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

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ABSTRACT. In Part II we extend four-dimensional model-building to the construction of action-quantal lattices embodying compound particles such as atoms and molecules. We discuss how atomic electrons and molecular rotations and vibrations fit into such lattices. It appears that here, too, Nature will optimally simply encode physical information, e.g., recording atomic fine structure data "economically". We go further into the relation between the corpuscular and the wave state in connection with our models.

We explain *inter alia* a) why the "quantal clocks" and wave lengths going with complicated atoms correspond to the appearance of "whole-atom quanta" and b) why atoms in their ground state do not radiate.

Suggestions follow from our research as to 1) finding (proportions of) some natural constants, 2) "Universal unification", since it relativizes the difference between "forces" and other ("particle") fields, and 3) geometrizing the physical world and its laws on the basis of a consistently action-metrical point of view.

RESUME. *Dans la deuxième partie, nous étendons la schématisation à quatre dimensions à la construction des réseaux de quanta d'action matérialisant des particules composées, comme des atomes ou des molécules. Nous examinons comment les électrons atomiques et les rotations et vibrations moléculaires s'insèrent dans de tels réseaux. Ici aussi, la Nature code simplement de manière optimale l'information physique, par exemple en enregistrant "économiquement" les données de la structure fine atomique. Nous approfondissons dans ce contexte la relation entre les états corpusculaire et ondulatoire.*

Nous expliquons entre autres a) pourquoi les "horloges quantiques" et les longueurs d'onde associées aux atomes compliqués correspondent à l'apparition de "quanta d'atomes entiers" et b) pourquoi les atomes dans leur état fondamental ne rayonnent pas.

Notre étude suggère la possibilité 1) de trouver certaines constantes naturelles (ou leurs rapports), 2) d'une "unification universelle", car ce travail montre que la différence entre les "forces" et les autres champs ("particulaires") est relative, et 3) d'une géométrisation du monde physique et de ses lois sur la base d'un point de vue cohérent vis à vis de la métrique d'action.

5. The action-quantal structure of non-elementary particles, such as atoms

We start from the two-particle wave equation [24, p. 89]

$$i\hbar\frac{\partial}{\partial t}\psi(x_1,y_1z_1,x_2,y_2z_2,t)=[-\frac{\hbar^2}{2m_1}(\frac{\partial^2}{\partial x_1^2}+\frac{\partial^2}{\partial y_1^2}+\frac{\partial^2}{\partial z_1^2}) -\frac{\hbar^2}{2m_2}(\frac{\partial^2}{\partial x_2^2}+\frac{\partial^2}{\partial y_2^2}+\frac{\partial^2}{\partial z_2^2})+V(x_1,y_1,z_1,x_2,y_2,z_2,t)] \psi(x_1,y_1,z_1,x_2,y_2,z_2,t), \tag{1}$$

where m_1 and m_2 are, say, the masses of the proton and electron of a free H-atom, in which V only depends on relative coordinates $x = x_1 - x_2$, y and z. Introducing the total mass $M = m_1 + m_2$, the reduced mass $\mu = m_1m_2/m_1 + m_2$ and coordinates X, Y, Z of the centre of mass we get

$$\psi(x,y,z,X,Y,Z,t)=u(x,y,z)U(X,Y,Z)e^{-i(E+E')t/\hbar}, \quad -\frac{\hbar^2}{2\mu}\nabla^2u+Vu=Eu \quad , \quad -\frac{\hbar^2}{2M}\nabla^2U=E'U. \tag{2}$$

(See Ref. 24, p. 90.) Here E is associated with the relative motion of electron and proton, and E' with the motion of the atom as a whole.

The first one of equations (2) especially interests us because of a very remarkable feature. Whereas the product $u(\mathbf{x})U(\mathbf{X})$ tells us something about the probability that, the atomic centre of mass being at $\mathbf{X}$, proton and electron are separated by $\mathbf{x}$, the factor $e^{-i/\hbar(E+E')t}$ is actually *extremely* remarkable. It holds that, in the atomic compound's existence as a process in time, an action-quantal periodicity manifests itself with the period $\Delta_1 t = 1/\nu = h/E + E'$, $E + E'$ representing the *total* energy of the atom. This corresponds to the equally remarkable experimental phenomenon that, in our performing, say, Young's interference experiment with atoms, the wave length $\lambda = h/p$ is defined by the momentum

p of the atoms *as wholes.* Conclusion : as to its action-quantal essentials –periodicity in time and the related spatial periodicity implied by the wavelength $\lambda = h/p$– an atom acts as a whole, electrons, nucleus and virtual photons connecting them being integrated into *one* series of action quanta of duration $\Delta_1 t = h/E + E'$ each. (Compare Fig. 7, illustrating four-dimensional action-quantal wave slices; the whole-atom slices in our case have a timelike dimension of $ic\Delta_1 t$.)

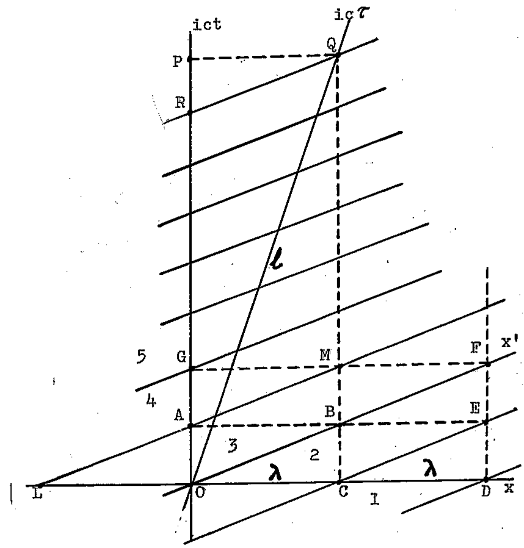

Figure 7. The wave slices of a freely moving particle; if it starts covering a circular orbit of length $2\pi r = OC = \lambda$, all slices turn helical and become mutually coincident.

What interests us here is: How can we construct a four-dimensional understandable model of the existence in time of atoms, with action quanta as its building blocks, *that realistically reflects what both formalism and experiment teach us about an intrinsic de Broglie period that apparently is also associated with compound particles as wholes ? Of course* the existence in time of a complex atom, too, just like that of everything else in the Universe, consists of mere action quanta; that is, of a simple series or a complicated lattice of such quanta. Actually, our idea that the Universe is "merely" a lattice of action quanta, of which atoms as they exist in time are sub-lattices, does not only follow from our own theory containing that the world is realistically four-dimensional and that processes, *that is, action instead of energy*, constitute its basic stuff, whereas the latter only appears as indivisible quanta. For current theory, too, though not being realistically four-dimensional, still implicitly contains that everything which physically matters follows from action. Compare, e.g., Ref. 18 pp. 162, 226 and 234, where we see that all physical observables follow from the Lagrangian. Because of the well-known relation $W = 1/ic \int Ldt$ for the action W this implies that all observables, *as phenomena or processes existing in time*, derive from action. The necessity of quantization then makes our lattice theory unescapable in a four-dimensional conception which, for the rest, derives an *a priori* plausibility from the primacy of the quantization of inherently four-dimensional action, from which all other quantizations follow. Of course, our theory of a four-dimensional Universe consisting of action quanta, conversely, *naturally and realistically* explains both *why* everything three-dimensional follows from the Lagrangian and *why* all quantizations derive from that of action.

Note as to the above problem of the appearance of whole-system quanta that the prominent figuring of a whole-system Hamiltonian in the Dirac and comparable equations of motion for compound particles, which Hamiltonian co-defines wavelength and frequency of the waves and internal clock associated with the system as a whole, is already indicative of the *action-quantal integration* at stake here. We can also surmise that the relevant integration reflects a simplifying translation into an action-physical master law of what we three-dimensionally see as various physical laws contributing to the formation of the relevant compound system. This would embody a similar simplification by the action point of view as the Principle of least action implies in comparison with the equations of motion. At least, the quantal integration amounts to an as yet non-recognised constraint with respect to known physical laws.

We now start considering what action-quantal lattice might embody a hydrogen atom's existence in time. In Fig. 7 (that is essentially Fig. 4 of Ref. 5, to which we refer those unfamiliar with it) we see how an electron's worldline l and action-quantal slices look like if the particle K moves freely. How does this change if it covers a ground-state orbit of length $2\pi r$ in a H-atom? (We realize our using a simplifying Bohr-approximation.) The quantal slices will actually bend into a *helical shape* because of the closed orbit. It is easily seen that, because of $\lambda = 2\pi r$, the circular bending will result in that C, D and all other points on the x-axis with coordinates $x = n\lambda$ (n is integer) will coincide with O, whereas $B, E, \ldots$ will cover A. It is also easily seen that this implies that in $O, A, G, \ldots$ the 0- and 2π-phases of all successive quantal slices in K's existence are physically present. We see all slices $1, 2, 3, 4, \ldots$ *transform into identical helically-shaped "tubes" covering each other.* (The radius of the helices is r.) This simple geometrical situation in Minkowski space has far-reaching consequences, i.e., a radically simplifying effect as to the action-quantal model we are constructing of the hydrogen atom. For we have now to envisage:

a) Because B will cover A, F will cover G etc. we see a feedback channel originate. For $OA = OB = 0$, $AG = BF = 0$ etc. in the action metric with its contiguity relations defined by K's periodical movement. Via the equi-action "plane" OBF... in its new helical shape we can get from $O, A, G, \ldots$ to R and P, that are all action-metrically contiguous now. (Compare that, in algebraic formulation, the action corresponding, e.g., to OB is $W = Et - \mathbf{p} \cdot \mathbf{x} = mc^2 \Delta t - p\lambda = mc^2 1/\nu - ph/p = mc^2 h/mc^2 - h = 0$, in which $\Delta t = BC/ic$ equals one action-quantal period in K's existence.) Thus we have a similar feedback channel in our atom's existence –via which, *inter alia*, retroactive signals can be transmitted, say, from P to O– as we saw in the Zitterbewegung (see Ref. 12). The helical shape of the relevant action-quantal slices creates an action-metrical *shortcut* through space. (The channel has actually a tube shape because radius r is in some measure uncertain ; we go further into this below.)

b) Because all slices of Fig. 7 mutually cover in being bent to helices –e.g., comparing slices 2 and 3 we see O of 2's 2π-phase cover L of 3's 2π-phase B, of 2's 2π-phase cover A of 3's 2π-phase and C of 2's 0-phase cover O of 3's 0-phase– all "successive" action quanta in electron K's existence *actually fuse. So one quantum continuously suffices to represent –that is, in fact, to "encode"– K's contribution to the atom.* (In Sect. 8 we go into for how long such situation endures.) In the first place, this amounts to an essential simplification as compared with the current atomic model in which massive electrons appear that correspond to $\nu = mc^2/h$ action-quantal periods per second. In the second place, our new model can explain *why* whole-system quanta –"disregarding" components– appear with compound particles such as atoms, quanta that manifest themselves in such particles' internal clocks and wavelengths as discussed above. We elaborate this now.

c) Our model requires an action "investment" of only one quantum for K's enduring existence in time as implementing a sub-process of the atom's existence. That is, such sub-process's action is *virtually infinitesimal* even as compared with the action of $\nu = m_e c^2/h$ quanta per second going with a free electron, let alone a free atom. This means that the action K would correspond to if it were free is available for processes other than its orbital rotation (such as the atom's existence in time).

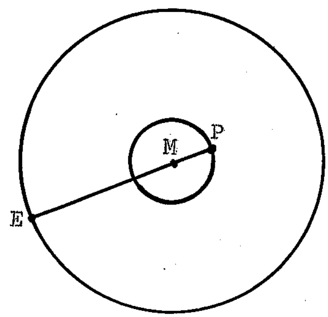

Figure 8. An electron and a proton rotating about the centre of mass M.

As to the existence in time of our atom's proton P (see Fig. 8, where E is the electron and M the centre of mass) we can argue as follows (using a self-evident notation). $m_p : m_e = EM : PM = v_e : v_p$ because P and E have equal rotation periods. Thus $m_p v_p = m_e v_e$ and $\lambda_p = h/m_p v_p = h/m_e v_e = \lambda_e$. Further, $m_p/m_e = m_{op}(1-v_e^2/c^2)^{1/2}/m_{oe}(1-v_p^2/c^2)^{1/2} \approx m_{op}/m_{oe} = 1836,109$, where m_{op} is P's rest mass.

Matters would be optimally simple if m_p/m_e would exactly equal the integer 1836. For then P's orbit would be $1/1836th$ part of the electron one which, because of $\lambda_p = \lambda_e$, would result in exactly 1836 orbits being covered by λ_p. Fig. 7 considered for this case shows then that an analogous bending of, say, quantal slice tube 2 as we discussed for the electron makes C cover O, B and E cover A and F cover G because $\lambda_p = OC$ is 1836 proton orbit lengths now. The result would be similar to that in the electron case : quantal slice 2 would not only cover helical slice 3, but all subsequent and former helical ones, too. Again, one helical protonic slice "tube" would suffice to represent or *encode* the continuous periodic proton movement. Once more a periodic sub-process in a compound particle would absorb a virtually infinitesimal amount of action, viz. h.

Because actually $1836,109$ is *not* integer, we have to choose between two alternative hypotheses to get things straight.

1. Correcting factors make $1836,109$ become 1836. Half the difference is made up by the above factor $(1-v_e^2/c^2)^{1/2}/(1-v_p^2/c^2)^{1/2} \approx (1-1/137^2)^{1/2}$ because $v_e/c = \alpha \approx 1/137$ (see d below) and $v_p \ll v_e$ (α is the fine-structure constant). So we get $m_p/m_e \approx 1836,06$. Matters are further complicated by the orbits being "tubes" rather than sharp lines and by their not even being exactly circular in the ground state. The latter circumstance is due to $1/2 \times 2\pi/\alpha \approx 432$ reflections per rotation of virtual Coulomb photons on both K and P (see Ref. 22, pp. 353 and 357).
2. We take the logical step –suggested by the state of matters with electron K– of extending our coded-information idea (compare Sect. 1f and Refs. 5 and 9) radically by assuming that $-m_p/m_e$ being integer or not –one protonic action-quantal helical slice encodes P's orbital movement completely. Such helix suffices because all the movement's information –radius r, velocity (by the slope of the helix), P's mass (by the parameter OA in Fig. 7), spinor-wave properties,...– are encoded by it without a material proton being necessary.

We extend the coded-information idea here in three respects : a. it is applied to the articulation of compound systems (i.e., their "fine structure" as to components, or rather sub-*processes*), b. it refers to *corpuscular* systems, too, whereas as yet it has been only applied to the way *waves* encode physical information about properties of corpuscular systems in a non-corpuscular language or data code and c. the code is now implemented by properties (the structure) of action-quantal *lattices* rather than those of mere individual (slicelike) quanta and series thereof.

If hypothesis 1. would be correct, P's rotation as a process would be represented by a similar helical quantum slice as the electron's, though a more "tightly folded" one. Virtually all action of the atom's existence in time is then embodied by its trunk action-quantal series with frequency $\nu_{at} = m_{at}c^2/h$, which explains the appearance of the whole-system wavelength $\lambda = h/p_{at}$, too.

The difference with the model corresponding to hypothesis 2. is mainly esthetic : If one λ_p winds over exactly 1836 orbits, our lattice model of the atom shows one more timelike periodicity ; otherwise, the single helix encoding P shows kind of "precession". Still, the esthetic point of view may not be neglected.

We positively do not assume that, *in addition to* the helices encoding their relevant information, material electrons and protons (nuclei) appear in atoms if no interaction requires such "embodiment" of the relevant encoded data. For this would leave Nature more complicated than it could be –which it seldom is. For the rest, the coded-information idea in general and how it appears to explain now the phenomenon of whole-atom quanta make us think of Feynman's words : "Truth can be recognized by its beauty and its simplicity".

Also note in the above connection that in a four-dimensional world, in which events, *processes*, are the primary elements to work with, rather than objects, *there is an a priori logic* in decomposing four-dimensional process-like atoms into sub-*processes* (rotating electrons, protons,...) rather than decomposing three-dimensional object-like atoms into object-like parts (electrons,...). A four-dimensional (process-like) compound is *characterized* by its sub-*processes* rather than by the sub-objects we will associate with object-like compounds ! And we saw the world become simpler by our making models attuned to this state of matters.

d) If hypothesis 1. under c) would appear to be correct, the action-quantal model of the hydrogen atom would lead to *a relation between the proton and electron rest masses and the fine-structure constant* α. To make this clear we first elaborate the result of Ref. 22 referred to above. It contains that for the electron orbit and a virtual photon V implementing the proton-electron attraction the relation

$$t = \frac{2\pi r}{v_e} = \frac{Ar}{c} \tag{3}$$

holds, where $A = 2\pi/\alpha$ is the number of times V travels to and fro before being absorbed (p. 352). Therefore, t is both the duration of an orbital rotation and V's lifetime so that one virtual photon is absorbed and re-emitted per rotation. In Fig. 7 we have

$$\frac{BC}{OC} = \frac{PQ}{OP} = \frac{OC}{OP} = \left| \frac{2\pi r}{ic\frac{2\pi r}{v_e}} \right| = \left| \frac{v_e}{ic} \right| = \frac{v_e}{c}.$$

(Mind that OP corresponds to one rotation and $2\pi r/v_e$ to its duration.) Now we see from (3) that $v_e/c = 2\pi/A = \alpha$. That is, the factor $(1 - v_e^2/c^2)^{1/2}$ of c) l. above that, in our hypothetical case, contributes to making $m_{op}/m_{oe} = 1836,109$ still lead to the integer number of 1836 proton orbits fitting on one λ_p, equals $(1-\alpha^2)^{1/2}$. This implies the relation indicated above. For as soon as the other perturbing factors contributing to $\lambda_p = 1836 \times 2\pi r_p$ are precisely figured *we can derive* α *from the ratio* 1836, 109.

More generally we can *a priori* expect that even more simplifying coherences than $\lambda_e = 2\pi r_e$ and $\lambda_p = 1836 \times 2\pi r_p$ are required to make the action-quantal lattices embodying various atoms and other compound systems optimally fit. This may imply some definite proportions between constants of Nature, which would simply mean that –now more understandable and "picturesque"– *quantization* requires such proportions !

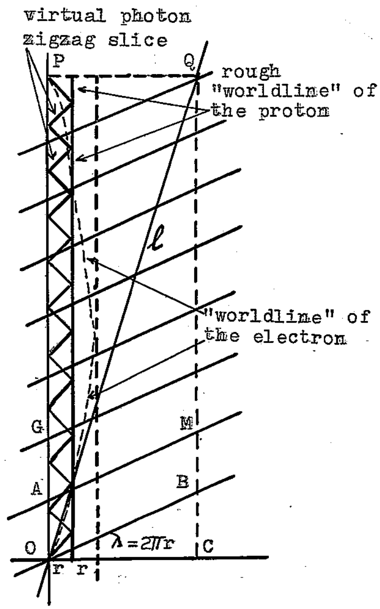

Figure 9. The zigzag slice of a Coulomb virtual photon in a four-dimensional picture of a hydrogen atom; we used the same letters as in Fig. 7 for corresponding point-events.

e) In the action-quantal lattice going with the hydrogen ground state the virtual-photon quanta fit as indicated in Fig. 9. Above we referred to the fact that each Coulomb photon lives one electronic rotation period, witnessing on an average $2\pi/\alpha - 1 \approx 862$ reflections on proton or electron before being absorbed. Note that the (spiraling) zigzag paths of such photons, too, embody feedback shortcuts through Minkowski space because their worldlines and quantal slices are parallel all over their lengths.

f) We now turn to periodic processes in compound systems other than the electronic and protonic ones in H-atoms we discussed above. I.e., atomic-electron rotations in non-ground-state or non-hydrogen cases, molecular rotations and vibrations and (quasi-periodic?) quark and gluon movements in hadrons.

1. With the $n = 2, 3, \ldots$ orbits of hydrogen $2, 3, \ldots$ electronic wavelengths fit on those orbits (we take the case of circular orbits). Comparing this with Fig. 7 we see that for $n = 2, D$ and all points on the x-axis satisfying $x = 2k\lambda$ will cover O in the helical bending (k is integer) ; E will cover A etc. It is easily seen that *two* helical quantal slices (say, 1 and 2) will now suffice for encoding the $n = 2$ electronic rotation. Generally, n_1 helically shaped quantal slices will encode an electron in the orbit $n = n_1$, $l = n_1 - 1$. For atoms other than hydrogen we can argue similarly, a finite number of λ's always fitting on an orbit. In all such cases the action investment in the sub-processes is virtually infinitesimal, which leaves all action available for implementing the trunk quantal series, with $\nu_{at} = m_{at}c^2/h$, of the atom as a whole.

2. A problem arises for atomic-electron movements corresponding to $l \neq n - 1$, nuclear movements in non-hydrogen atoms, quark movements in hadrons, etc., which are non-circular. We hypothesize that nothing fundamental changes here as compared with the circular cases other than that appropriate deformations of the relevant encoding helices and photonic zigzags now appear. This assumption contains that *all* sub-processes in a non-interacting compound system C are encoded by a relatively small number of code quanta in C's lattice and explains why, such sub-processes requiring only a relatively infinitesimal investment as to action, even complicated molecules in principle demonstrate a whole-system wavelength $\lambda_m = h/p_m$ in, say, grating interference experiments. The action-quantal models of compound systems so introduced generally "only" *amount to an irrefutable consequence of realistic four-dimensionality and action quantization, and actually embody the latter in a realistic and imaginable* –though no doubt yet "simplistic"– *way.* This is the more important because quantization of action is at the basis of all other quantizations and even of the very failure of Classical Theory [21, p. 42].

3. Our now generalized virtually-zero hypothesis as to the action contribution of sub-processes in compound systems is much strengthened by the circumstance that for well known periodic movements such as molecular rotations and vibrations, too, we can prove their specific action to be zero. In a realistic action physics this means that their –in any case non-vanishing– representation in the quantal lattice embodying the relevant molecule's existence in time can hardly be different from a small set of code quanta, comparable to the case of atomic electrons: additional periods virtually do not consume additional action. (Remind that we have only the case in view of non-interacting, free, compound systems.)

First consider rotation of a molecule N consisting of two identical atoms with distance r and total mass M. In such case we have (see Ref. 25, p. 640) $E_r = E_{kin} = 1/2J\dot{\varphi}^2$, where J is the moment of inertia and φ the rotation angle. Further $p_\varphi = J\dot{\varphi}$ and $\oint p_\varphi d\varphi = 2\pi\dot{\varphi}J = mh$. This means in our case, in which $J = 1/2M \times (1/2r)^2$ for each of the two atoms, that we see for such atom

$$\oint p_\varphi d\varphi = \oint 1/2M \times (1/2r)^2 \frac{d\varphi}{dt} d\varphi = \oint 1/2M \times 1/2r \times \frac{d\varphi}{dt} \times 1/2r d\varphi$$
$$= \oint 1/2M \frac{ds}{dt} ds = \oint 1/2Mv ds = p \times 2\pi \times 1/2r = mh,$$

where the meaning of the symbols is self-evident. Thus we have $2\pi \times 1/2r = mh/p = m\lambda$, where p and λ are the momentum and wavelength going with each of the molecule's atoms. Because $2\pi \times 1/2r$ is the length of each atom's rotational orbit we see here that in all rotations *an integer number of* λ*'s fit on an orbit.* That is, we have a similar situation here as with atomic electrons, and we find the atom's rotation, that is, one more sub-process in N's existence, to be encoded by appropriate helically-shaped action quanta: n_1 code quanta if $n_1\lambda = 2\pi \times 1/2r$. Only a nominal action n_1h is "invested" in this sub-process, too, so that again N's trunk quantal series will "absorb" virtually all action associated with N's existence. The helical slices encode all characteristics of the rotation, e.g., rotation velocity (by the slope of the helices) and momentum p (by λ) and therefore also the mass of the rotating atoms. Mind that our above assertion about the specific action being zero has to be conceived in the same sense as for the electronic orbital movement in H-atoms (compare a) above) : a zero-action feedback channel is embodied by molecular rotations, too.

Rotation-vibration interaction and (related) non-constant values of r complicate matters but can at most effect deviations from an "esthetic" optimum simplicity referred to earlier (and corresponding to $2\pi r = n_1\lambda$) in that the encoding slices are deformed and/or show the kind of "precession" mentioned in the third paragraph following c) 2. above, in connection with the protonic rotation in H-atoms.

We now consider the action corresponding to molecular *vibration*, first proving that for the lowest energy case E_0 the action going with one period, $W = \int Edt - \int pdr$ is zero. Using a well-known notation we have $E_0 = 1/2\hbar\omega_0$, with $\omega_0 = (C/m)^{1/2}$, in which m is the relevant atomic mass and C a constant characteristic for the specific vibration. $\Delta t = 1/\nu = 2\pi/\omega_0$. Thus over one period $\int Edt = E_0\Delta t = 1/2h$. Further, $p^2/2m = E_0 - 1/2Cx^2$, or $p^2 = 2mE_0 - mCx^2 = 2mE_0 - m^2\omega_0^2x^2$. In the extreme position $p = 0$, so that then

$$x_e^2 = \frac{2E_0}{m\omega_0^2} = \frac{\hbar\omega_0}{m\omega_0^2} = \frac{\hbar}{m\omega_0} \quad \text{and} \quad x_e = (\frac{\hbar}{m\omega_0})^{1/2}.$$

For a complete vibration we see then

$$\begin{aligned}\int pdx &= 4\int_0^{x_e} pdx = 4\int_0^{x_e}\sqrt{2mE_0 - m^2\omega_0^2x^2dx}\\ &= 4\int_0^{x_e}\sqrt{1-\frac{m\omega_0^2}{2E_0}x^2d(\frac{m\omega_0^2}{2E_0})^{1/2}x} \times (\frac{2E_0}{m\omega_0^2})^{1/2}\sqrt{2mE_0}\\ &= 4\sqrt{2mE_0}\sqrt{\frac{2E_0}{m\omega_0^2}}\int_0^1\sqrt{1-y^2}dy = 4\times 2\frac{E_0}{\omega_0}\int_0^1\sqrt{1-y^2}dy\\ &= 8\times\frac{1}{2}\hbar\int_0^{1/2\pi}\cos^2 tdt = 4\hbar\times\frac{1}{4}\pi = \frac{1}{2}h.\end{aligned}$$

This means that the action $\int Edt - \int pdx$ over one complete vibrational period is $1/2h - 1/2h = 0$. We can argue this way for all vibrating atoms of the molecule separately.

For $E_1 = 3/2\hbar\omega_0$ etc., the next energy levels, we can argue similarly, finding $W = 3/2h - 3/2h = 0$, $5/2h - 5/2h = 0$ etc.

So we see the remarkable fact that the action contribution of one more sub-process, viz. the vibration of molecules, is infinitesimal. Therefore, in an action-quantal model of a molecule's existence in time, such process can be encoded by a limited set of more or less zigzag- or helically-shaped action-quantal slices representing only nominal action. Mind here that in order to exist at all a physical process has to consist of minimally one quantum of action. Thus, by encoding all periodic sub-processes in compound systems by means of (small sets of) roughly helically- or zigzag-shaped –in any case "periodic"– quantal slices, Nature acts optimally economical and at the same time effects the appearance of whole-system quanta even for complicated molecules so long as they only interact, or manifest themselves, as wholes, such as in interference experiments.

The extension of the original coded-information theory of Refs. 5 and 9 embodied by the foregoing relates to the wave-particle problem in two respects. First, we time and again used the wave concept in discussing sub-processes though having corpuscular compound systems in view. This is not contradictory because a location eigenvalue for such system (corpuscularity) may very well leave, say, internal rotations sufficiently (interaction-)free to exclude the appearance of separate location eigenvalues of the relevant components, which leaves them wavelike. Second, our model is partly relevant to the wavelike state of a compound system C as such, too, by its mere explanation of the appearance of whole-system quanta, which continue to exist in the wave state that, as we saw earlier, corresponds to 1^0 non-enforcement of a location eigenvalue and 2^0 a fusion of components. As to 2^0 the coded model of atoms and molecules we discussed now contributes the (specification of the) insight that such fusion already appears *to a high degree in the corpuscular state, too*, so far as the relevant "wavelike" components do not separately participate in outward interactions of C. This makes the result of our relevant discussion in Sect. 4 more precise. The (realistic) wave state completes such fusion in the sense of a complete blurring out of any articulation along (spacelike) equi-action planes, which leaves a core code of C's component-processes that will be discussed in Sect. 8.

In most realistic cases spatial localization of, say, an atom will at the same time cause its electrons to interact so much with the environment (collisions, energy absorptions, photon emissions,...) that these components and their movements are more independent and "substantial" than corresponds to the mere passive existence which is encoded as discussed. Then, an advanced integration of components into whole-system quanta will not already appear in the corpuscular state. All of this accentuates our earlier remark that wavelike and corpuscular-like states appear in various gradations, dependent on outside interactions and various measures of (location) eigenvalue enforcement, such enforcements in general being inversely proportionate to the dimensions of the equi-action margins ("uncertainties") for the relevant observables.

4. Our action-quantal model of compound systems can in principle be extended to all their (quasi-)periodic sub-processes such as quark and gluon movement in hadrons and electron and virtual photon processes implementing the chemical bond in molecules. Action-quantal sets will appear as encoding helices and "zigzags", varying as to number and shape of their elements, with which we still expect optimum simplicity and "economy". Quantal models of compound systems differ from the action-quantal series embodying elementary particles in that such components-encoding sets now complicate the trunk quantal series of the frequency $\nu = mc^2/h$ by their being linked up with it in ways to be discussed in Sect. 8.

Just as in the original coded-information theory of Refs. 5 and 9 a relevant (measurement) interaction may decode or materialize the code signal into an imaginable or substantive (object-like) phenomenon such as mass or spin, e.g., an interaction separately involving atomic electrons, such as ionization, materializes such components, at the same time suspending or perturbing the atom's integration to whole-system quanta. Of course, this is one of the reasons why one cannot perform interference experiments with, say, photon-emitting particles.

Remark. We know little about the orbits of quarks in a three-quark hadron. *A priori* considerations suggest them to be less simple than those of the quark and anti-quark in positronium-like mesons but not fundamentally more complicated than, say, the atomic orbits in a three-atom molecule. This makes us expect them to be represented by deformed helices in our code model as, correspondingly, gluons can be expected to be represented by deformed zigzag slices comparable to the photonic one sketched in Fig. 9.

If no lattices of mutually fitting action quanta could be associated with all compound systems and their internal processes, so that symmetry and simplicity allow the latters' *shorthand representation* by code quanta, the experimentally established appearance of whole-system quanta would be unaccountable.

More generally we may say that incidental problems with our theory cannot be insurmountable because of the fundamental fact that quantization of action is inescapable. *For compound systems in a* *four-dimensional and realistic conception such quantization virtually amounts to their embodiment by lattices of mutually fittingly joining action quanta, this even constituting a constraint that has to guide our insights about how natural laws and sub-processes in compound systems work.*

g) A *prima facie* drawback of our somewhat "Bohr-like" (though four-dimensional) atomic and other models is that they do not directly correspond to the relevant wave functions $\psi(\mathbf{r}, t)$, e.g., for the hydrogen electron. Via $P = \mid \psi \mid^2$ such function produces observation probabilities that locate the H-electron more "diffuse", less definite as to its distance r from the proton, than our model does. However, there is a crucial difference between the nature of our model and that of the one suggested by the $\psi(\mathbf{r}, t)$ following from the Schrödinger equation. For ψ, via $\mid \psi \mid^2$, refers to *observation* probabilities, *the influences of both measurement disturbances and the interaction-related substantialization (de-coding) referred to in the second paragraph of f) 4. above being included.* This means quite a difference from our non-perturbed, "clean", optimally simply encoding, model in which, e.g., atomic electrons do no more realistically appear than spinning-top-like corpuscules hide in polarized matter waves *representing* them codedly. Our model is precisely *changed*, *disturbed*, by any measurement intervention to which ψ refers. Mind also in this connection that, e.g., the virtual photons realistically figuring in our atomic model do not do so (that is, appear as discrete but unobservable realistic quanta) in any observables-related ψ-function or -model. So there is a fundamental difference between any ψ-related model and our own.

Further note that mixed (superposed) states can be represented by our "clean" models indeed. E.g., helical code quanta for both an $n = 1$ and an $n = 2$ electron may very well simultaneously appear in our quantal model of a H-atom, their probability amplitudes being defined by their way (measure) of connection with the system's trunk quantal series and a possibly related propensity of substantialization. (Compare here their similarity to self-interacting photons or mesons accompanying charged particles and hadrons that is further discussed in Sect. 7.) Mind here further that because our encoded components and sub-processes are all represented by virtually infinitesimal amounts of action, action metric implies that mere virtually infinitesimal action shifts suffice to transform alternative coded pure states into each other, which contributes to making such related states (in various measures) be simultaneously "virtually present" in the system. (Compare for such "simultaneous presence" in particular Refs.5. and 8.)

6. Some more phenomena that can be explained by the action-quantal model of atoms

Our starting-point was to find out how a realistic, imaginable action-quantal model of compound systems could explain their apparent association with whole-system quanta.

However, such model explains more than that. In the first place, it clarifies why an atom in its ground state does not radiate. For the relevant electrons *are not really there at all*, since they are virtually integrated in the atom as a whole. In the absence of outside intervention they are, optimally economically, only represented in a shorthand code which does not imply a rotating charge, either. Such code contains no more than instructions for what interactions have to appear if various outside agents manifest themselves. In the same vein, "accelerated charges", e.g., in stationarily vibrating molecules consisting of ions, do not radiate.

Another problem can now be explained, too, viz. the fact that, if an electron falls back from an orbit corresponding to an energy E_2 to one of energy E_1, the emitted waves (photon) from the very start appear to be attuned to the total energy $E_2 - E_1 = h\nu$ going with the emission. By "producing" the frequency ν, the electron falling back appears to take full account of its future energy in the E_1 orbit *as soon as the emission* –that is, the reduction of the electron's energy– *starts.* In our model, this is no problem because the transition $E_2 \to E_1$ corresponds to a virtually infinitesimal shift in action physics. For the helical slices corresponding to the E_2 and the E_1 orbit, respectively, both represent a nominal action of a few h. The difference is virtually zero and, therefore, the E_2 and E_1 situations are what we called action-metrically contiguous in Refs. 3 and 5: one can instantaneously go over into the other and *the information contained by one is easily available to the other, too.* This suffices to explain the problem stated above. What happens is that the code quanta corresponding to E_2, by an action-physically (virtually) infinitesimal shift, transform into the relevant E_1 code quantum or quanta, the new situation corresponding to an energy for *the atom* that is $E_2 - E_1$ smaller than before.

In Ref. 8 we gave an explanation of the retroactive effect, that is, of feedback communication in timelike directions which has to appear in some experiments unless we abandon conservation of (angular) momentum [4, 6, 7]. The explanation exclusively referred to systems in the wave state.

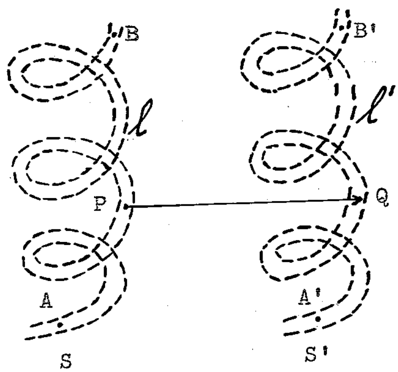

Figure 10. What happens at B may have repercussions even at A' because two actiometrically infinitesimal shifts suffice for getting from B to A and from A to A', respectively, if the relevant compound system is in the wave state.

Above and in Ref. 12 we also explained mechanisms implying retroaction in corpuscular systems, such as those embodied by the helical slices going with atomic electrons or molecular rotations, by zigzag virtual-photon slices as in Fig. 9 or gluonic worldlines and also by the helical "wordlines" of Dirac particles –or rather, of the massless charges C associated with them– performing the Zitterbewegung. Now we argued in Sect. 4 that in the wave state a virtually complete fusion of system components will appear because a) they mutually "overlap" realistically in equi-action planes and b) in such state a separate identity of system components will generally lack an interactional, that is, functional, basis, so that then, much more often than in the corpuscular state, only their mere coded representation will continue. Still, the above-mentioned retroaction mechanism might continue to be operative in the wave state, too (at least with compound systems), thus producing an additional explanation of retroaction in such state. For if we consider Fig. 10 we see feedback communication to be possible between A and B in helical slice l (whose 0- and 2π-phase equi-action "planes" have been sketched). That is, an action zero is needed in order to transform situation B into A by covering the relevant equi-action plane or line by which A and B are connected. Besides, however, a shift over PQ of the compound system

S of which l is a code quantum is action-metrically infinitesimal if in S's wave pattern PQ is parallel with such pattern's equi-action planes. From this we see that in the wave state what happens at B can still have influenced at A and even at A', which again means a feedback integration of the relevant process; we see a microprocess functioning "as a whole" indeed. The continuation of corpuscular feedback mechanisms into the wave state may generally apply to all kinds of compound particles showing some kind of helical or zigzag equi-action "shortcut". In Ref. 12 we compared, moreover, the corpuscular feedback mechanism as appearing in the Zitterbewegung on the one side, and the one only pertaining to waves of Ref. 8 on the other. We suggested that the relation between the two mechanisms might fit in the general isomorphism between corpuscular and wavelike action-quantal processes. The new mechanism for waves discussed above complicates matters somewhat for compound particles, and the relation between the corpuscular and one of the two wave-associated mechanisms is not yet clear for them. An *elementary* (Dirac) particle's Zitterbewegung helix may be fundamentally lost in the wave state (compare Sect. 4), so that matters probably differ here from the compound case.

7. Various coherences and problems

1) In our theory, the existence in time of a component P of a compound particle S is a mere quasi-immaterial, economically information-encoding, action-physical communication channel. In case of outside interactions of S, P starts embodying a separate identity and (substantial) action (momentum, wordline, charge,...) so far as it plays a separate part in such interaction with which P's integration in system S's trunk quantal series is also suspended. E.g., think of ionization or of an atom P interchanged by molecule S in a chemical reaction. Generally, S's interactions are triggered by outside influences on S's action-quantal code system that co-embodies its properties.

Being "particles" that never separately appear, quarks might play a part fundamentally different from that of other system components such as electrons. Still, the circumstance that they can be exchanged between hadrons suggests their having a separate identity. It may be that quarks play a part in hadrons which is comparable to that of "charge C" in the Zitterbewegung of electrons (compare Ref. 12 and Sect. 3 above); that is, that they are elements of the action-generating process action quanta going with corpuscular particles are (just as the field potentials that articulate matter wave slices cannot but be instrumental in producing the action going with wavelike quanta). Such idea would not exclude their being exchanged and could also make their isolated appearance non-functional as to the generation of action. In the wave state they would mutually fuse as discussed with Fig. 5 because of their no longer having any separate interactional function and their "equi-action overlapping".

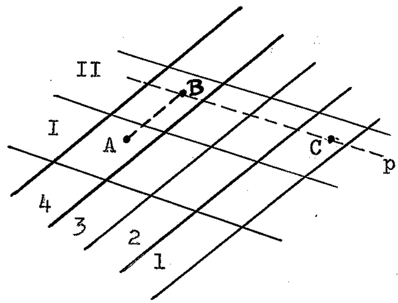

Figure 11. If an elementary interactional action phenomenon has to appear in a few mutually intersecting now-hyperplanes (such as AB and BC) at a time, its space dimensions tend to be infinitesimal.

2) Our general point of view indicates that all truly elementary particles (electrons, muons, quarks,...) are in principle *point-like* if they are in the corpuscular state, in contradistinction to hadrons and other compound particles, that have finite dimensions. For in our theory a corpuscule is nothing but an eigenvalue of the observable "location" originating from a (say, measurement) interaction process that action-physically is symbolized by Fig. 11. If the action-quantal series I, II,... would isolatedly appear, no action-physical difference would exist, for the internal functioning of the process, between situations B and C on a same equi-action plane p. An interacting action-quantal series 1, 2, 3,..., however, e.g., representing a measurement intervention, causes B and C to be no longer action-physically equivalent for the (interaction) process as a whole. For as to co-interacting series 1, 2, 3,... situations B and C make a difference of three quanta, that is, $3h$. This may cause a relevant elementary-particle-like *phenomenon* P to appear definitely, say, at B instead of (unobservedly) being operative on p, in the stretched mode current theory associates with "uncertainty". In principle, B will be infinitely small, that is, point-like. For, a shift of phenomenon P in either the BC or the BA direction, or in on in-between, now definitely *changes* *the local action-physical situation.* There is no longer an action-physical equivalence, for the process, of all p-situations that could stretch P to a wavelike or even a merely finite extension. Mind here that the local *action-physical* situation has to be as definite, in our deterministic theory, as the corpuscular situation has in classical physics. Only if it action-physically *does not make a difference* where P appears on p it is stretched over p indeed (with which p corresponds to some moment in P's existence). For the rest, in order to "constrain" P to a point the measurement intervention has to correspond to more than one additional quantal series such as 1, 2, 3,... because in four-dimensional space P would otherwise be only constrained to, e.g., a line-shaped locus.

Compound particles cannot be constrained to a point because the action phenomenon they embody is too complicated an action-quantal *lattice* for not having a finite extension even in the corpuscular state. (Mind that even for an electron only "charge C" is pointlike, in contradistinction to the action-producing Zitterbewegung.)

Within the above scope the concept "particle" does not have more "material" a meaning than to be a (partly idealized) local concentration of observable phenomena (mass, spin, charge,...). This indeed corresponds to an –interaction-dependent– local concentration of realistic *action-physical* processes rather than some permanent "thing", "little spherical mass". This also makes it once more clear that generally no corpuscules are "hidden" in matter waves. In the corpuscular phenomenon there is no boundaries other than those of the relevant action-physical processes; there is no extra "spherical boundary plane".

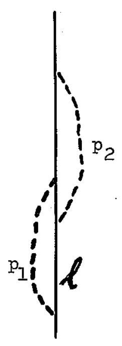

Figure 12. "Self-interacting" entities such as p_1 and p_2 co-define the "trunk" system's physical properties.

3) In Sect. 5 f) 4. we indicated how in specific interactions, co-triggered by relevant information-encoding quanta, the latter could substantialize to roughly independent physical entities such as electrons. Now it forces itself on us that there is some analogy between on the one hand the way in which, say, "self-interacting" (virtual) photons can accompany a non-interacting charged particle P and on the other hand how in our atomic-electron model the electrons accompany atoms. (See Fig. 12, in which l is P's worldline and p_1 and p_2 are self-interacting photons.) In both cases outside interactions do not occur but their *potential* appearance is embodied by "self-interacting" photons and electrons, respectively, that "substantialize" as soon as they actually cooperate in triggering a relevant interaction. That is, in both cases the photons and electrons (etc.), by being there, encode specific properties (charge, chemical valence,...) of the relevant system P, (co-)triggering corresponding interactions as soon as appropriate agents manifest themselves. In both cases they may also start to embody a separate energy, momentum etc., at the same time contacting and/or crossing over to such agent as virtual photon, valence electron and the like. E.g., prior to the interaction $n \to p^+ + e^- + \bar{\nu}_e$ the electron may have been helically encoded, afterwards assuming its separate energy etc., somehow like previously self-interacting photons do in becoming Coulomb-force transmitters.

One consequence of the above "unification" of property-encoding and influence-transmitting action quanta, whether they embody self-interacting photons or "self-interacting" (orbital) electrons, might be important. For though "self-interacting" electrons' electric charges will be instrumental in their triggering outside interactions of "their" compound system (as will, correspondingly, be the gluons "of" quarks), our new conception still may imply a common denominator for both kinds of property-encoding, influence-transmitting and/or interaction-implementing entities. That is, the difference between bosons transmitting the four fundamental forces of Nature, and other particles such as electrons that can encode ("interactional") properties *other* than charge or color, might be less fundamental than hitherto has been thought. An essential common feature of both categories is that their constituting action quanta are in a position to form shortcut communication channels allowing information or "forces" to cover finite distances in Minkowski space corresponding to infinitesimal action distances for the relevant process. Both kinds of action quanta allow or partially implement interactions by reducing the action-physical distance to zero between, e.g., two charged particles or an emission and an absorption event.

The conclusion from the foregoing is that it might be artificial, unnatural, to look for Unification Theories as to the mere four fundamental forces and their transmitting "particles", e.g., unifying them within a geometrical framework. On the contrary, it may be more consistent to look for a common basis and integration, *not merely of the force-transmitting action quanta* –fundamental-force transmitters more often than not being one-quantal phenomena [22]–, *but of all other kinds of action quanta jointly, too.* An essential point in this connection is that up to now we saw the existence in time of each kind of truly elementary particle as being constituted by a separate kind of action quanta. If we, however, could vary action quanta according to a few basic characteristics or modes of producing action, matters might become simpler, viz. if we would need fewer quantal parameters to reproduce them all than there are truly elementary particles. A joint integration of the force-transmitting and other kinds of action quanta may be implied by such new kind of symmetry, of "eightfold way". *We would substitute the systematization and unification of elementary particles and fundamental forces by ones of the real fundamental entities, viz. (kinds of) quanta of action, by a Universal Unification.*

It militates for such new approach that current Unification Theories will be ever more complicated and less and less imaginable and, in spite of various impressive aspects, as to others fly in the face of Feynman's quoted "beauty and simplicity". Mind also that as soon as we put four-dimensional processes first and foremost, rather than objects, *there is no longer a fundamental difference between "forces" and "particles": both correspond to processes in time*, embodied by (various kinds of) action quanta. Again, this suggests an *a priori* logic of jointly integrating quanta going with particles *and* forces. Of course, this does not prevent elementary force-transmitting bosons from having common characteristics, too, but they may be less special than hitherto has been thought.

A final point links up with the above. Einstein and others sought after a geometrization of all fundamental forces and/or of the world in general. The reason why success remained elusive up to now may be that such geometrization does not make sense in "artificial" geometries but, in the last resort, only does so in the sole natural one: action metric and geometry. Universal Unification as referred to above, in concentrating on action (quanta), might ultimately contribute to such geometrization. One point in this connection is that we can say that true *actions at a* *distance* do not exist in action physics, neither within nor between interacting systems. They do not because virtual photonic, gluonic, helical-electronic etc. action quanta generally effect action-metrical contiguities, direct physical contacts, between entities influencing each other "from a distance" in Minkowski and/or Euclidean space. This is an essential feature that, e.g., virtual photons, gravitons, the atomic-electron helical slices shortcutting Minkowski space in timelike directions and the instances effecting EPR "action at a distance" have in common: they make interacting agents that are mutually distant in conventional metric physically contiguous in action metric. (See above and Refs. 3, 5, 8 and 22.)

Within this scope and that of the general geometrization indicated above we may conceive the various "helices" so prominently figuring in the quantal lattices we discussed as kind of *geodesic lines* (of length zero) in the action world and metric. There may be some point in more generally deriving physical laws and forces from how such *action-metrical* geodesics deviate from straight lines in Minkowski space, in a similar way as more specifically gravitational laws and forces can be derived from how *Riemannian* geodesics deviate from such lines. (In order to get in a position to do so we should first translate the relation between Riemann geodesics and gravitational forces in terms of action quantities.) This may fit in reconstructing physics from action-quantal lattices and their symmetries and information codes. (Compare Sect. 9 and also the last paragraph of Sect. 8.) Note in the above connection that the Principle of *least* action actually amounts to the law that systems cover *geodesics* in four-dimensional action space! This is very relevant in action-geometrizing the world.

8. How do coding quanta link up with an atom's trunk action-quantal series?

Because an atom's existence in time (if undisturbed) is a regular, periodic, lattice of action quanta, the mutual junctions of its various kinds of quanta –those of its trunk series, its electrons, nucleus and virtual photons– embody an essential feature of its action topology, structure. Actually they constitute a shorthand version of it, though still complicated by the potential appearance of superpositions of state. As is already clear from what we indicated at the end of Sect. 5, such action-physically contiguous alternative states of a same atom can no less appear in its (semi-)corpuscular lattice condition than in its wave state, for which we discussed them earlier [5, 8].

In Ref. 22 we found that in atoms precisely one virtual (Coulomb) photon happens to be "spent" per electronic rotation if $n = 1$, whereas for $n = 2, 3, \ldots$ the situation is analogously simple (compare also below). This means that after every rotation period a virtual-photon quantum links up with either the nucleus or an $n = 1$ electron or, as will appear to be most consistent below, with the trunk series of the relevant atom. In order to find a plausible model for how the quanta encoding atomic electrons link up with such atoms' trunk quantal series we can argue as follows.

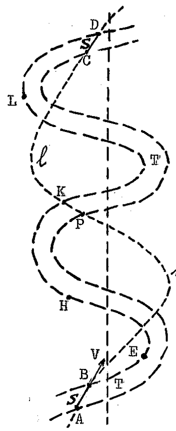

Figure 13. One-quantal helix T and corresponding worldline segment S; if S has to make contacts in its O- and 2π- phase ends, it has to do so in virtually parallel positions at A and D, respectively. Action metric allows this.

A matter-wave action-quantal slice T is associated with a worldline segment S of the relevant particle (i.e., an atomic electron) with proper length $\mid ic\Delta\tau \mid = \mid ich/mc^2 \mid = h/mc$ and a direction four-vector in Minkowski space that corresponds to the tube-like slice's position and slope. At the same time, S has to fit on the electron's worldline l. (See Fig. 13.) The latter, in contradistinction to T, witnesses only one spiral turn per completed rotation of the encoded electron. This has as a consequence that, if with the *one*-quantal helical slice T we make consistently correspond only *one* worldline segment S, such S –that in the most obvious picture does not make a twist in its short existence in smooth T, that is, its direction four-vector $V \equiv (iE/c, \mathbf{p})$ is rather stable during its lifetime $\Delta\tau$– can only shortcut Minkowski space M (as the helix T does correspondingly) on a certain condition. This condition relates to the fact that its 0- and 2π-phases have to link up with other quanta while their sectional environments *have virtually parallel directions* because of V's stability. I.e., if S in the position AB would link up at 0-phase A with the atom's trunk series, its 2π-phase end *will naturally link up with* *such series at* D, exactly one rotation period later, because CD (e.g., in contradistinction to PK) is S's first position on l succeeding AB that is parallel with AB. Mind here that an action-metrically infinitesimal shift can transform AB into CD, e.g., B, E, H, K, L and D being action-metrically contiguous on equi-action helix $BEHKLD$. Thus, just like our helical T shortcuts M because of action-metrical conditions, segment S does so in connecting A and D by linking there up with the trunk series. S embodies a shortcut *by worldline* l through M, so completing one electronic quantum of action per rotation. This model would imply that Nature encodes such rotation in the simplest possible way, committing a minimum of one quantum of action (or, say, four quanta, viz. if an $n = 4$ orbit is at stake) per basic event (i.e., rotation). Such model would even more make matters optimally simple because, a relevant Coulomb photon's lifetime being one rotational period, too, such photonic quantum, the electronic one, *and* the trunk series would jointly link up at A and D, successively, and so on, one electronic, one photonic and an integer number of trunk quanta periodically being completed before linking up in $0 - 2\pi$-phase junctions.

Of course, the above hypotheses would have consequences for the proportions between the masses of electrons and of the particles constituting atomic nuclei. After corrections have been made as to all relevant kinds of perturbing factors, as already partly mentioned in Sect. 5, *the conditions for making the action-quantal lattices of all atoms and other compound particles and their sub-processes optimally simply "fit" might produce several new relations between natural constants. A priori*, the latter can be expected to be attuned at making the "action-quantal lattice of Nature" consistent, optimally simple and beautiful.

In all, the above model harmonizes with our earlier enunciated Principle of least complication [12] that now may be formulated as containing that *action-quantal lattices tend to show the optimum simplicity still in a position to produce the observable phenomena.* The Principle of least action fits in it as the special case of action-quantal *series* tending to be optimally *short.* Least action *does not yet incorporate* (our new realistic and imaginable forms and models of) *quantization, as Least complication* –in referring to realistic lattices of mutually fitting action quanta– *does indeed.* In a way our action-quantal atomic model illustrates both principles in combining the minimum action h going with electronic movement with the simplest possible lattice topology still encoding all relevant information (atomic properties). For the rest it is consistent in our optimum-simplicity conception that we forget all about separate "real" atomic electrons and their energy and momentum, apart from their encoding helical quanta: there is nothing but action quanta, momenta etc. being our visualized models or "classical" constructions. After getting the helical-slice idea, *inter alia*, via $Et - \mathbf{p} \cdot \mathbf{r} = 0$, we forget about $E, t, \mathbf{p}$ and $\mathbf{r}$!

In view of what we assumed about the junctions of atomic-electron quanta with the atom's trunk series it would be consistent to think of quanta encoding molecular rotations or vibrations as being "attached" to the molecular trunk quantal series after each period of such movements.

An alternative model as regards the attachment problem, at least in the case of atomic electrons, would be that the electron slices never make direct contacts at all with the trunk series, there only being an indirect contact via the Coulomb virtual photon quanta. Apart from that such conception would be less plausible in the rotation and vibration cases, another drawback is that symmetry arguments suggest that, then, the atomic-nucleus slice, too, just as the electron's, would only make contact with the trunk series via the Coulomb virtual-photon quanta. This does not produce a very clear picture.

On the other hand, our first model, starting from three-branch junctions of trunk, electron and photon quanta, may be very useful in continuing the coding-quanta idea from the corpuscular to the wave state of compound systems such as atoms and molecules, as will become clear below.

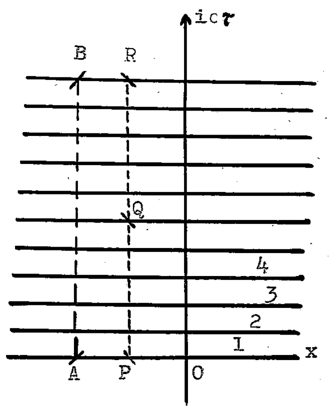

Figure 14. The "rudimentary" coding system for processes in the wave state of compound particles; the locations and characteristics of component quantal junctions $(A, B, P, ...)$ define such processes without this implies any perturbation of the proper wave phenomenon.

In Sect. 4 and in connection with Fig. 10 it became clear that in the wave state of atoms the electronic helices and, more generally, the fine structure, will be blurred, as will the one of molecules etc., too. Actually, we saw that a virtual fusion of components appears (though we argued with Fig. 10 that the "blurring" needs not frustrate the functioning of the helical feedback mechanism). All the same, it would be satisfactory from a standpoint of both optimum coherence and optimum simplicity if, in the wave state, too, the fine structure of compound systems were codedly preserved in the optimally simple way still harmonizing with such state. This may now be the case indeed on account of what we hypothesized above, viz. that all coding quanta –corresponding to atomic electrons and virtual photons, to molecular rotations and vibrations, etc.– characterizing a compound system C to detail make periodical contacts with C's trunk quantal series, viz. in specific $0 - 2\pi$-phase mutual junction points, lines or planes. E.g., an atomic electron rotating in the $n = 2$, $l = 1$ orbit would then be encoded in the wave state, too, viz. by the periods AB and PQ (see Fig. 14). AB defines the number of trunk quanta of the kind $1, 2, 3, \ldots$ between successive periodical mutual junctions $A, B, \ldots$ of the relevant electronic worldline, that is, code quanta, and the trunk series. At the same time, PQ defines the number of trunk quanta between two corresponding Coulomb photon-quantal attachments. Because for $n = 2$ two λ's fit per orbit and a Coulomb-photon quantum makes contact with some $0-2\pi$-phase quantal junction (we preliminarily assume: a trunk-quantal junction) at the rate of one junctional contact per λ [22], the mere proportion $AB/PQ = 2$, in combination with the fact that *two* coding quanta between A and B (etc.) go with one orbital rotation, defines the $n = 2$ situation. In fact, the duration of a rotation and, therefore, the lifetimes of the relevant encoding electron and photon quanta, are defined (encoded) by the mere numbers of trunk quanta over AB and PQ. Such lifetimes, in turn, define the photon's energy and the corresponding electric attraction and the radius of the orbit. (The trunk quanta $1, 2, 3, \ldots$ of Fig. 14 embody an internal clock by which all durations of sub-processes characterizing system C, and their proportions and phases, are internally defined.) More generally we may say that, given the physical laws –which are "known" to a relevant system simply because they are operative– Nature needs to encode no more information than

a) the number of trunk-clock ticks between junctions such as A and B or P and Q, and

b) the nature of such junctions, i.e., the number, kind, relative momentum,... going with the joining action quanta,

in order to sufficiently define all possible (periodic) sub-movements characterizing compound systems in their wavelike states. That is, mere numbers, junctional data and natural law suffice for reconstructing the phenomena and models we establish in relevant (measurement) interactions, such as the $n = 2$ electronic "movement" in the above case.

The physical information code suggested above may combine the *maximum* articulation encodable in a wavelike quantal lattice (that ideally shows no structure in proper-spacelike directions) with the *minimum* information by means of which a quantal lattice can be encoded, viz. the number and duration of the quanta of its branches and the topology and nature of their mutual junctions, on the understanding that all branches encoding sub-processes have junctions with a dominating trunk quantal series. Such (hypothetical) *other kinds* of information about the nature of a compound system C that might *not* be encodable in this way if C is wavelike can only be induced to manifest themselves in a relevant measurement via nonlocal communication as, e.g., appears in EPR experiments. Note that the appearance of such nonlocality demonstrates that *in principle* physical situatigons (data) can nonlocally have influence, but *here* we discuss the special case of information about *the nature* (components, fine structure) *of compound systems*, which, if our above model is correct, might as a general rule be encoded by the *local* waves. Note in particular that the above model of information-encoding for wavelike compound systems is precisely attuned at preventing any blurring or erasing of the relevant information in the wave state of such systems. Finally note that in our model the information in question, though encoded (represented) in the "local" waves, all the same does not manifest itself in the specific wave behaviour (e.g., in interference experiments) apart from the wavelength going with the trunk quantal series. Nevertheless it is in a position to reproduce any aspect of the articulation (or specific properties) of the compound system as soon as it is experimentally tested or becoming relevant.

What we said in the last paragraph about encoding maximum articulation by means of minimum information militates in favour of the above model in that it shows "beauty and simplicity"; indeed, if correct it would illustrate the Principle of least complication, for wavelike compound systems no less than for corpuscular ones.

Again, the foregoing strongly suggests the appearance of various definite proportions between natural constants, such as about masses and the strength of fundamental forces, as conditions for allowing consistently fitting topologies of all possible compound systems of Nature. Note here that not only AB and PQ of Fig. 14 have to correspond to integer numbers of trunk quanta, but that *similar integer proportions are predicted by our theory* in cases such as heavy atoms, with which the numbers of trunk quanta per various electronic rotations and photonic lifetimes differ radically from the situation in hydrogen, so that rather many numbers have to fit correctly. Only elaborate (computer) calculations –think of perturbing factors such as nuclear binding energies, mutual potentials of electrons and retardations with virtual photonic reflections and emissions– will allow verifications here. We assume various natural constants and proportions to be attuned at making the "branches" and trunk of action-quantal lattices mutually fit in the framing of atoms etc. Conversely, they therewith co-define what compound systems are possible and stable. Ultimately, the symmetries and "chemistry" of micro-particles would boil down to a coherent set of properties and variations of action quanta and of natural constants co-defining what internally fitting and stable lattices can be framed from such quanta. *All of this actually amounts to a realistic, imaginable and four-dimensional model of quantization, of how complete action quanta link mutually up.*

9. Some architectonic principles of the physical Universe

In coherence with what we discussed about encoding information, optimum simplicity and a possible Universal Unification a rough outline of architectonic principles of the world may look like as follows.

1) Action quanta are varied in Nature by means of simple code variables: frequency, transformability, phase relations between spinor components,...;
2) Apart from, *inter alia*, the frequency of their trunk quantal series, compound systems are varied by their component-encoding and generally roughly helically or zigzag-shaped code quanta and the junctions thereof with the trunk quanta; the coding quanta also embody communication channels allowing feedback in timelike directions;
3) In the model to which 2) refers, molecules are one more grade complicated than atoms because the latter themselves (or rather, the processes in which they participate and those defining them) are now codedly represented in the molecular quantal lattice, at least so far as the molecule is fairly free and the atoms do not separately engage in outside interactions. Because molecules, just like

atoms, can manifest themselves as matter waves, so that the action of their sub-processes is substantially integrated in their trunk series, our argument of Sect. 8 strongly suggests that *all* molecular sub-processes, too, are in the wave state codedly represented as in Fig. 14, this corresponding to a corpuscular-state representation by helical- or zigzag-like coding quanta that directly link up with the molecule's trunk quantal series.

4) In the elementary biological systems DNA molecules are we see Nature take a step further as to coded information: characteristics are now encoded by A, C, G and T molecules in well-defined order. A fundamental difference with the foregoing, however, is now that DNA molecules will not appear freely; they always interact with other chemical agents. Therefore, a four-dimensional trunk series of whole-system quanta *will not appear now; it is the mere coding principle that, again, manifests itself in a more encompassing way.*

Natural laws may then ultimately be derived, according to the Principle of least complication, from general conditions that, *given the observed phenomena*, optimize the simplicity of action-quantal lattices representing compound systems and of the principles on which the encoding of physical information is organized. All of this may be a generalization of how the equations of motion (that is, observed phenomena) can be derived from the Principle of least action. Actually, our starting point that the vacuum as such is non-existent (only a relic of the ether), and that the only real contents of the Universe is the quantal lattices, makes such point of view –i.e., an optimum coherence and simplicity of the architectonic principles of the relevant lattices, which now *embody* physical law– have a great measure of plausibility. Instead of "Principle of least complication (or: optimum simplicity)" we might also speak of "Principle of minimum information redundancy" or "Principle of optimally simple data encoding".

A concrete example of how a tendency to optimize the simplicity of quantal lattices could induce interactions may be provided, e.g., by the chemical interaction $H+Cl \rightarrow H^{+}+Cl^{-} \rightarrow HCl$. This could ultimately be due to the circumstance that both H^{+} and Cl^{-} have simpler sets of valence electrons than H and Cl have (i.e., an empty and a completed set of outer-shell electrons, respectively). So quantization in the realistic and imaginable sense of the formation of optimally coherent and stable lattices of undivided action quanta that mutually fit well may embody a major tendency defining what systems and what interactions will appear and what will not.

10. Concluding remarks

Our general conception of natural laws as based on the structure and symmetries of the four-dimensional action-quantal lattice L (with its sub-lattices of which the world actually consists, rather than on "innate tendencies" in more or less isolated three-dimensional objects, raises a more general point. Viz.: *How large-scale and how subtle are L's symmetries, how far-reaching, "intelligent" and consistent is its coherence?* The circumstance that *distances* can be derived from, are implied by, greater lattices or patterns (compare Sect. 2 and Ref. 8) might be only a particular example of the fact that more generally local situations are a function of greater patterns (in L) rather than the reverse. Could it be that, as to the measure of coherence in Nature, including evolution, history and human fate, the known natural laws are only the tip of an iceberg? Moreover: If it is events rather than objects to which natural laws relate, is it not consistent then to assume them to govern the outcomes *as such* of events, too? Is natural law indifferent to them as such? Least action seems to be not. Retroactivity, making feedback possible, strongly points in the same direction. Generally, a conception of natural law as symmetries, patterns, in L in principle greatly enlarges its scope, making it far more encompassing, less restricted to local domains. It might far less be local coincidences that determine the outcome of processes, developments, than we hitherto thought. Why, further, would only *micro*-processes (partly) function as wholes, since in many macro ones –e.g., the falling of dice–, too, "uncertainty" margins exist within whose latitudes decisions might be "co-orchestrated" in accordance with L's possible macro-symmetries?

Mind in particular that a situation as suggested would mean *more* order, *more* coherence –more rationality– in Nature instead of less: It is chaos and pure chance which would be reduced as compared to current conceptions, and that especially with respect to large-scale processes.

It is in a same spirit of aspiring to coherence, rationality, that we tried to construct understandable models here, considering them to be the very essence and purpose of scientific research at all. In this connection it might be that much of the "fundamental-uncertainty" – and anti-understandable-models-minded positivistic philosophy, which is less interested in reality and its coherent explanation than in formalism, is an unconsciously pursued elaborate excuse for evading detailed thinking about and detailedly explaining Nature – that is, producing detailed Aha-Erlebnisse about reality. For by such evasion one can create or accept sufficient vagueness ("uncertainty", absense of coherence,...) to allow the repression of a direct confrontation with admittedly otherwise appearing paradoxes that hardly leave other solutions than abandoning certain deep-rooted prejudices, especially about metric (think of action metric), determinism, retroaction and the traditionally accepted corpuscular nature of particles (think of the coded-information idea).

References

[24] L.I. Schiff, *Quantum Mechanics* (Int. Student Ed., McGraw-Hill Intern., Auckland etc., 1968).

[25] G. Joos, *Lehrbuch der theoretischen Physik* (Akad. Verl. Geest & Portig, Leipzig, 1959).

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