DARK MATTERS AND HIDDEN VARIABLES OF UNITARY SCIENCE:
HOW NEGLECTED COMPLEXITY GENERATES MYSTERIES AND CRIDES,
FROM QUANTUM MECHANICS AND COSMOLOGY TO GENETICS
AND GLOBAL DEVELOPMENT RISKS

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Abstract

The unreduced many-body interaction problem solution, absent in usual science framework,
reveals a new quality of emerging multiple, equally real but mutually incompatible system
configurations, or “realisations”, giving rise to the universal concept of dynamic complexity
and chaoticity. Their imitation by a single, “average” realisation or trajectory in usual theory
(corresponding to postulated “exact” or perturbative problem solutions) is a rough simplifi-
cation of reality underlying all stagnating and emerging problems of conventional (unitary)
science, often in the form of missing, or “dark”, entities and “hidden variables”. We show how
the application of unreduced interaction problem solution and the ensuing concept of dy-
namic complexity provides the desired causally complete and intrinsically unified solutions
to respective unitary science problems in the entire range of complexity levels, from elemen-
tary particles and cosmology to emergent consciousness and modern development crisis, im-
plying real, essential and urgently needed progress.

- Fundamental and general unreduced interaction, emergent particles (Page 2)
- Lowest complexity sublevels: space, time, mass, forces, quantum relativity (Page 15)
- Complex-dynamic cosmology, emergent Universe without missing entities (Page 36)
- Higher complexity levels, sustainable development without crises (Page 54)
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Unitary science strongly reduces the dynamically multivalued result of any real interaction process, giving rise to violated causality and “unsolvable” problems [1-30]

The standard self-description of today’s mainstream science results typically presents it as an “almost” complete and quasi-perfect system of knowledge (being the only possible rigorous/objective one), which is apparently confirmed by the spectacular progress of science-based modern technology. Even the obvious huge contradictions, persisting “mysteries” and growing “difficult” problems of the standard science framework, from quantum mechanics and cosmology to biology and consciousness (see e.g. [1,7-12,14,16-19,28-34]), are presented as “encouraging challenges”, although they remain unsolved for many decades (or even a century) already, while the mainstream theories and the scientific method itself do not show any signs of real change and capacity to qualitatively evolve, within the dominating scholar science paradigm.

In order to understand the true origin of this evident conflict between the empirically based knowledge success and irreducible limits to the standard science development, we should specify the underlying key features of the scholar scientific method. Its well-known “positivistic” basis is reduced to “mathematically decorated empiricism”, or mathematically ordered observations, not necessarily (and in fact rarely) supported by the consistent physical origin of proposed formal “laws”. Thus, the main output in scholar theoretical physics, a “theory” supposed to account for observed phenomena, structures and behaviour, is reduced to purely abstract and simplified mathematical structures emerging in their own realm of “nicely symmetric” mathematical objects and rules and just arbitrarily assumed to correspond to observations.1 Starting already from elementary particles and fields, the studied objects’ physical nature, origin and properties, forming the fine-tuned,

1 Hence the related esoteric idea, indistinguishable from irrational belief and favoured by many leading theoretical physicists, about the “mathematical reality” [35-43] underlying the observed physical reality and being not less objectively real, but much more fundamental than the latter.
cause-and-effect tissue of reality, are largely neglected in such purely mathematical “modelling” and its occasional (always only partial and inconsistent) correlations with real structure behaviour.

No wonder that this dominating formal kind of “explanation” tends to favour simplest possible mathematical structures in its abstract “theories”, revealing no true, causally complete physical origin of described real structures and laws. These conventional theories are well represented by the paradigmatic example of yet rather tangible structure of “Newtonian trajectories”, but strongly tend today to “phase space” and other purely abstract “spaces”, ever more separated from real system behaviour and configuration in real physical space (the latter remaining itself a persistent mystery in scholar science, together with time). As we shall see below, the real, interaction-driven system dynamics and emergent structure, starting from the simplest objects of fundamental physics, are very far from those oversimplified “models” of positivistic “theories”, which actually provide the largest possible simplification of reality. As opposed to postulated abstract and separated structures of conventional positivistic theories, the emergent, interaction-driven and intrinsically unified character of unreduced physical reality we explicitly derive in our approach implies the key role of dynamics.

If we want to avoid the fundamental deficiency of conventional positivism, we should start our consistent description of real world structure and dynamics from the unreduced analysis of the underlying universal process of interaction, which progressively gives rise to all observed structures, properties and laws of their behaviour. It is obvious that one should start from the simplest possible interaction configuration, without any additional assumptions and artificially introduced features.

Such simplest initial configuration of structure-forming interaction is given by two effectively structureless and homogeneously interacting entities, or “protofields” [1,2,5-12,14]. Taking into account the observed universal properties, one can specify one of them as the physically real electromagnetic (e/m) protofield (eventually responsible for electromagnetic features) and another one as the equally material gravitational protofield (leading to gravitational attraction), without any real limitation or special assumption for our unified interaction description. The homogeneous interaction between protofields in the form of their uniform attraction is the simplest
structure-forming kind of interaction, again without any special assumptions for the following interaction analysis.

The most general and assumption-free mathematical expression of this simplest interaction configuration is provided by the Hamiltonian form of existence equation [1,2,5-12,14] generalising e.g. the Hamilton-Jacobi and Schrödinger equations, but actually only fixing the fact of interaction and initial system configuration (it is also self-consistently confirmed by further analysis):

\[
[\mathcal{H}_g(\xi) + V_{eg}(\xi,q) + h_e(q)]\Psi(\xi,q) = E\Psi(\xi,q),
\]

where \(\xi\) and \(q\) stand for the degrees of freedom of gravitational and e/m protofields respectively, \(\Psi(\xi,q)\) is the system state function, \(\mathcal{H}_g(\xi)\) and \(h_e(q)\) are the generalised Hamiltonians of free gravitational and e/m protofields, \(V_{eg}(\xi,q)\) is the potential of their (attractive) interaction, and \(E\) the system Hamiltonian eigenvalue, or generalised energy. As shown elsewhere (and below), the generalised Hamiltonian and energy express a suitable measure of unreduced dynamic complexity. We emphasize the absence of time in our initial problem formulation, since time, together with other intrinsic features, is an emergent entity in our fully consistent approach and appears dynamically in the interaction development process.

Note that all interactions between the protofield elements are included in the compact form of eq. (1) as expressed in a more explicit form of existence equation for arbitrary many-body interaction [1,2,11,13-24,28,29]:

\[
\left\{ \sum_{k=0}^{N} h_k(q_k) + \sum_{l>k}^{N} V_{kl}(q_k,q_l) \right\}\Psi(Q) = E\Psi(Q),
\]

where \(h_k(q_k)\) is the generalised Hamiltonian of the \(k\)-th system component (here protofield element) in its “free”, “integrable” state (in the absence of interaction), \(q_k\) stands for the degrees of freedom of the \(k\)-th component, \(Q = \{q_0,q_1,\ldots,q_N\}\) by definition, \(V_{kl}(q_k,q_l)\) is the interaction potential between the \(k\)-th and \(l\)-th components, \(\Psi(Q)\) is the system state function, and the summations are performed over all system components numbered from \(k,l = 0\) to \(k,l = N\) (the total number of interacting entities). If we separate in \(\mathcal{H}_g(\xi)\) all the free Hamiltonians \(h_k(q_k)\) and interactions \(V_{kl}(q_k,q_l)\) between the gravitational protofield elements (with all their degrees of freedom grouped in \(\xi\)) and in \(h_e(q)\) the corresponding free Hamiltonians and
interactions between the e/m protofield elements (grouping their degrees of freedom in \( q \)), then the detailed existence equation (2) is reduced to the compact form (1), with \( V_{eg}(\xi, q) \) representing the sum of interactions between elements of different protofields. Or if we are interested in detailed interactions only between the e/m protofield elements, while considering the gravitational protofield as a quasi-homogeneous underlying medium, or “matrix”, then the same many-body existence equation (2) takes the form

\[
\begin{bmatrix}
    h_0(\xi) + \sum_{k=1}^{N} h_k(q_k) + V_{0k}(\xi, q_k) + \sum_{l>k}^{N} V_{kl}(q_k, q_l)
\end{bmatrix}\Psi(\xi, Q) = E\Psi(\xi, Q),
\]

where \( q_0 \equiv \xi \) groups the eventually “hidden” degrees of freedom of the gravitational protofield, \( Q = \{q_1, \ldots, q_N\} \) includes the explicitly appearing degrees of freedom of the e/m protofield, and \( k, l \) vary now between 1 and \( N \). With \( Q \to q \) in eq. (3), the latter turns again into the reduced notation of eq. (1), without any loss of generality.

The equivalence of various forms of existence equation (1)-(3) is confirmed by its further analysis in terms of (known) eigen-solutions for some, usually explicitly observed participants of the global interaction process, represented by the e/m protofield for eq. (1):

\[
\Psi(\xi, q) = \sum_{n} \psi_n(\xi) \varphi_n(q), \quad h_c(q) \varphi_n(q) = \varepsilon_n \varphi_n(q),
\]

where \( \{\varphi_n(q)\} \), \( \{\varepsilon_n\} \) is the complete set of (orthonormalised) eigenfunctions and eigenvalues of the free e/m protofield, describing its local element excitations (with \( n \) enumerating localities and eigenvalues for them). Applying the standard procedure, we insert expansion (4) into eq. (1) and using the orthonormality of \( \{\varphi_n(q)\} \) obtain the system of equations for \( \psi_n(\xi) \), which is equivalent to any form (1)-(3) of existence equation:

\[
[h_g(\xi) + V_{nn}(\xi)]\psi_n(\xi) + \sum_{n' \neq n} V_{nn'}(\xi)\psi_{n'}(\xi) = \eta_n \psi_n(\xi),
\]

where \( \eta_n = E - \varepsilon_n \) and \( V_{nn'}(\xi) \) are matrix elements of the protofield interaction potential:

\[
V_{nn'}(\xi) = \int dq \varphi_n^*(q) V_{eg}(\xi, q) \varphi_{n'}(q).
\]
actually any other many-body system) is inevitably “unsolvable”, i.e. nonintegrable and nonseparable, in terms of “exact” (closed-form) solutions and therefore replaced in usual theory approaches to various many-body interaction problems by essentially simplified, integrable “models” that can be generalised as a separable “mean-field” interaction, with its “exact” solutions and their further, equally “exact” perturbative extensions:

\[ [h_\xi (\xi) + V_{nm} (\xi)]\psi_n (\xi) = \eta_n \psi_n (\xi), \]  

(7)

where \( V_{nm} (\xi) \) is just one simplest example among various other mean-field expressions of similar dynamic origin. However, what is definitely lost in any such model is the structure-forming capacity of the unreduced system interaction, or “emergence” in popular complexity science expressions, which is due to essential, dynamically evolving links between all interacting modes in (5), while all usual approximate models (7) are reduced to mechanical reproduction of the initially fixed system configuration.

In order to overcome those key limitations of usual analysis, we try to solve the unreduced system of equations (5) by the generalised effective (or optical) potential method [1,3,44], where the “effective field” of all interactions acting on a given component mode is not simplified by any averaging of other mode dynamics and therefore acquires qualitatively new properties giving rise to rigorously describable features of unreduced interaction complexity. This is achieved technically by expression in (5) of \( \psi_n(\xi) \) through \( \psi_0(\xi) \) in all equations with \( n \neq 0 \) using the standard Green’s function properties and further substitution of the obtained expressions in the equation for \( \psi_0(\xi) \), leaving us with a single equation:

\[ [h_\xi (\xi) + V_{\text{eff}} (\xi; \eta)]\psi_0 (\xi) = \eta \psi_0 (\xi), \]  

(8)

where \( \eta_n = \eta_0 \) is the eigenvalue to be found, the effective potential (EP) \( V_{\text{eff}} (\xi; \eta) \) is given by

\[ V_{\text{eff}} (\xi; \eta)\psi_0 (\xi) = V_{00} (\xi)\psi_0 (\xi) + \]

\[ V_{0n} (\xi)\psi_{mi}^0 (\xi) \int d\xi' \psi_{m'i}^{0*} (\xi')V_{n0} (\xi')\psi_0 (\xi') \]

\[ + \sum_{n,i} \frac{\Omega_{\xi}}{\eta - \eta_{ni}^0 - \varepsilon_{n0}}, \]  

(9)

\( \varepsilon_{n0} = \varepsilon_n - \varepsilon_0, \; n \neq 0 \) (also below), and \( \{\psi_{mi}^0 (\xi)\}, \{\eta_{ni}^0\} \) is the complete set of
eigenfunctions and eigenvalues for a truncated system of equations (system (5) without \( \psi_0(\xi') \)):

\[
\left[ h_\xi (\xi') + V_{nn'} (\xi') \right] \psi_n (\xi') + \sum_{n' \neq n} V_{nn'} (\xi') \psi_{n'} (\xi') = \eta_n \psi_n (\xi'), \quad n, n' \neq 0. \tag{10}
\]

Solving the effective interaction, or existence, equation (8) for \( \psi_0(\xi') \), we find other state-function components \( \psi_n(\xi') \) with the help of mentioned Green’s functions and then the total state-function \( \Psi(\xi, q) \) according to the initial expansion (4) (see below) [1-3,8-23].

Despite its externally simple expression in eq. (8), the effective problem formulation is equivalent to the initial formulation (1)-(3), (5) and remains equally nonintegrable, because of the complicated EP dependence on the solutions to be found, eq. (9), explicitly revealing the essentially nonlinear system dynamics behind its seemingly linear initial formulation. Usual EP approach tries to get rid of those “unsolvable” difficulties by using perturbative simplification of the unreduced EP expression (9) (see e.g. [45]), leaving one with a version of ordinary mean-field approximation (7) and its severe limitations. If, however, we avoid any simplification of the full EP formalism (8)-(10), then it is not difficult to see that the revealed effective, dynamic nonlarity leads to the new quality of the unreduced problem solution with respect to all usual, “exact” or perturbative, solutions.

This key new quality is obtained as the essential, universally derived growth of the number of interaction problem eigen-solutions beyond their ordinary, “normal” set completely sufficient to form just one its physically real configuration (as a result of interaction development). Indeed, the number of eigen-solutions of the effective existence equation (8)-(9) is determined by the highest power \( N_{\max} \) of the characteristic equation for \( \eta \):

\[
N_{\max} = N_\xi (N_q N_\xi + 1) = N_{R} N_q N_\xi + N_\xi , \tag{11}
\]

where \( N_q \) and \( N_\xi \) are the numbers of summands in the sums over \( n \) and \( i \) respectively in eq. (9) (often \( N_q = N_\xi = N \), where \( N \) is the total number of interacting modes or, in general, the number of mode combinations), \( N_q N_\xi = N_{R} N_q N_\xi \) is the ordinary eigen-solution number for a physically complete system configuration, and \( N_{R} = N_\xi \) is the number of system realisations, i.e. its really emerging, equally probable but different configurations, each of them including the ordinary number of eigen-solutions \( N_q N_\xi \) and therefore incompatible with any other, equally physically complete system realisation.
While in any usual model and conventional science in general (including its complexity imitations) $N_{3R} = 1$ (because the unreduced interaction problem (5) is always replaced by a “tractable” approximation like (7)), in our case of interacting protofields and for any other real system we have $N_{3R} \gg 1$ (and in any case $N_{3R} > 1$ for any real interaction). In support of this algebraic derivation from the characteristic equation for the effective problem formulation, the plurality of (any real) system realisations is also obtained by the graphical analysis of the same equation (8) [1-4].

Equation (11) implies therefore that the mentioned new quality of the unreduced interaction problem solution due to its effective dynamic nonlinearity takes the form of permanent change of its plural, mutually incompatible realisations emerging in dynamically random order thus defined, as opposed to only one, unchangeable and fixed realisation (or trajectory) in any usual theory and description. We call the system dynamical splitting into many incompatible realisations, revealed as a universal property of unreduced interaction problem solution, (fundamental) dynamic multivaluedness, or redundancy, while the unrealistic case of only one system realisation, invariably considered in standard theory, is referred to as unitary theory, description and science (including actually the entire body of standard scientific knowledge) [1-3,11,14,28-30]. Note that various semi-empirical (and “computational”) imitations of complex dynamics in unitary science referring, in particular, to “multistability” and “multiple attractors” still contain only one system realisation of the same point-like unitary projection (corresponding to zero value of unreduced dynamic complexity, see below), since they deal always with a single trajectory structure or evolution, where different compatible, coexisting attractor structures or system states are consecutively taken by the smoothly evolving system with only formally inserted time variable (cf. our emergent time below).

As can be seen from eq. (11), in addition to $N_{3R}$ physically complete ordinary, or regular, system realisations, each of them containing the full set of $N_{q\xi}$ eigenvalues of emergent interaction result (system configuration), there is one more, separate set of “incomplete” number of $N_{\xi}$ eigenvalues insufficient to form a regular realisation and the corresponding observed interaction result. It is not difficult to see (also from the graphical analysis of the unreduced problem solution [1-4]) that this additional eigenvalue set constitutes the necessary special realisation taken by the system during its
transitions between regular realisations. This transient, distributed system realisation is called the main, or intermediate, realisation and provides the universal, physically real extension of the quantum-mechanical wavefunction and various distribution functions at respective complexity levels \([1,2,5-11,14,19,28]\). The reduced number of eigenvalues corresponds to transiently vanishing effective interaction between the system components in this “loose” realisation, where the system returns to a version of its initial state at the beginning of interaction process in order to form the next emerging strong-interaction state of regular, fully structured realisation.

At the considered lowest level of interacting, initially homogeneous protofields, each regular, strong-interaction realisation emerges physically in the form of squeezed and entangled concentration of the coupled protofield material called virtual soliton and giving rise to the localised, corpuscular state of thus dynamically emerging elementary particle and physical space point \(x\), while the extended main realisation, ensuring system transitions between such concentrated regular realisations, corresponds to the physically real wavefunction of the particle, \(\Psi(x)\), accounting for its undular properties. This rigorously confirmed result (see further details below) can be understood also in terms of physically transparent system instability with respect to regular realisation formation and change, where any small local density growth in the coupled protofield system gives rise to a self-amplifying protofield squeeze in that location followed by the equally inevitable extension after the maximum compression, driven by the same intrinsic instability of the neighbouring protofield interaction.

Returning to the rigorously specified dynamically multivalued structure of any real interaction process (1)-(5), we can now define the dynamically determined, a priori probability, \(\alpha_r\), of the causally random emergence of the \(r\)-th system realisation from the complete set of its \(N_{\Psi}\) realisations. Due to the equally probable emergence of each elementary realisation in the simplest, initially homogeneous system configuration, the dynamic realisation probability is obtained as

\[
\alpha_r = \frac{1}{N_{\Psi}}, \quad \sum_r \alpha_r = 1 .
\]  

(12a)

In the general case of inhomogeneous system, where elementary realisations may be not resolved individually and form actually observed dense groups, or compound realisations, we have
\[ \alpha_r = \frac{N_r}{N_{\text{R}}}, \quad \sum_r \alpha_r = 1, \tag{12b} \]

where the \( r \)-th realisation contains \( N_r \) elementary, not directly observable realisations. In particular, the inhomogeneity of the intermediate, wavefunction realisation is due to its dependence on the emerging system configuration, or generalised “space coordinate”, of respective regular realisations, \( \Psi(x) = \Psi(x_r) \). The above expression for the dynamic realisation probability, eq. (12a), takes then the form of the generalised Born rule, now causally explained and extended to any system dynamics [1,2,5-12,14,19-23,28]:

\[ \alpha_r = |\Psi(x_r)|^2, \quad \sum_r |\Psi(x_r)|^2 = 1, \tag{13} \]

where the last equation reflects the probability normalisation to 1 (similar to eqs. (12)) taking the usual integral form of wavefunction normalisation condition in the limit of closely spaced, quasi-continuous realisation distribution. Note that for corpuscular levels of complexity with dominating localised structures one will usually have here the generalised wavefunction, or distribution function, value instead of its modulus squared.

Since emerging system realisations determine all observed structures and motions (as further confirmed below), expressions (12)-(13) for the dynamic realisation probability actually provide the rigorously substantiated, universal definition of omnipresent dynamical chaos in terms of unreduced, multivalued interaction dynamics, essentially extending usual definitions of chaoticity within the ordinary, dynamically single-valued (unitary) theory. We can see that it is the fundamental dynamic multivaluedness itself that provides the unique, universal basis for the purely dynamic emergence of randomness within any observed structure and process, equivalent thus to the consistent definition and unified, realistic origin of (any) randomness as such, together with other, now clearly unified concepts, including nonintegrability, nonseparability, undecidability, and noncomputability [1-4,11,14,19,28,29]. While the standard unitary theory cannot consistently specify the intrinsic, fundamental origin of genuine dynamic randomness, replacing it with various imitative “signatures”, our unreduced interaction analysis finds it within any, even externally regular, or self-organised, structure (corresponding to the above compound realisation of eq. (12b) with \( N_r \equiv N_{\text{R}} \), see also the fourth section below). In particular, we provide the consistent theory
of genuine quantum chaos correctly passing to (equally consistent) classical chaos under the standard transition to classicality ($\hbar \to 0$) [1-3,14,44], which solves the stagnating quantum chaos problem of usual theory.

We can now provide the consistent and universal definition of dynamic complexity of any system or interaction process as another aspect and quantitative expression of their equally universal chaoticity. Dynamic complexity, $C$, is defined as any growing function of the number of system realisations, $N_R$, or rate of their change, equal to zero for the unrealistic case of only one system realisation (uniquely considered in usual theory) [1-4,8-24,28]:

$$C = C(N_R), \quad dC/dN_R > 0, \quad C(1) = 0,$$

where, for example, $C(N_R) = C_0(N_R - 1)$ or $C(N_R) = C_0 \ln(N_R)$. It means that it is the number of regular system realisations, beyond the special intermediate realisation of distribution (or wave) function, which determines the nonzero dynamic complexity of real systems. By contrast, the single realisation considered in usual theory often originates in the generalised distribution function, or main realisation, of the unreduced, dynamically multivalued system description, which reveals the nature of the unitary theory as effectively zero-dimensional, point-like projection of the unreduced, dynamically multivalued reality (also in connection to the generalised Born rule (13)). This unitary science projection may seem closer to reality for strongly localised self-organised behaviour with only one effectively observed compound realisation (cf. eq. (12b)) or “trajectory”, but as it always contains many different (though similar) realisations within its pseudo-regular shape, any real-world structure is both truly chaotic and dynamically complex, $C > 0$ (and practically always $C \gg C_0 = C(2)$). As we show here and elsewhere [1-30], it is this rough, ultimately simplified projection of dynamically multivalued reality onto zero-dimensional space of usual, unitary science which explains all its problems with “missing” matter, energy, “hidden variables” (i.e. realisations) and other apparent contradictions in real-system behaviour.

Another important property of the unreduced interaction result, complementing the key feature of dynamic multivaluedness, is the dynamic entanglement of interacting degrees of freedom (or system components) characterising the tangible physical quality (texture) of the emerging structure and expressed by the dynamically weighted combination of products of functions depending on individual interacting degrees of freedom (like $\xi$ and $q$
in eq. (4), see also below, eq. (16)). This physically real property is ignored in abstract unitary models and further amplified in our unreduced interaction analysis by the eventual dynamically fractal, hierarchic and multivalued (probabilistically changing) structure of the ultimate problem solution, obtained by application of the same unified EP method to solution of the (finite) sequence of ever smaller truncated systems of equations, starting from eq. (10) [1,2,8-11,14,16-23,28]. It is evident that causally random change of regular system realisations with the dynamically entangled structure at any level of this fractal hierarchy occurs through the reverse process of dynamic disentanglement of interacting degrees of freedom in the transient phase of intermediate realisation, or generalised wavefunction, which further clarifies the physically real structure of the latter.

We can now further specify the physical configuration of the emerging first level of interaction of our two initially homogeneous protofields. The measurable system density \( \rho(\xi, q) \) is obtained as the dynamically probabilistic sum of densities of all emerging, permanently changing system realisations, \( \{\rho_r(\xi, q)\} \), each of them obtained as the modulus squared of respective state functions (4) found by solution of the system of equations (5) with the help of the generalised EP formalism (8)-(10) [1-6,8-12,14,28]:

\[
\rho(\xi, q) \equiv |\Psi(\xi, q)|^2 = \sum_{r=1}^{N_{\text{tr}}} \rho_r(\xi, q) = \sum_{r=1}^{N_{\text{tr}}} |\Psi_r(\xi, q)|^2 , \tag{15}
\]

\[
\Psi_r(\xi, q) = \sum_i c_i^r [\varphi_0(q)\psi_0^n(\xi) + \varphi_n(q)\psi_0^n(\xi) + \sum_{n,i'} \frac{\alpha_{n,i'} \psi_{n,i'}^0(\xi') V_{\text{eff}}(\xi') \psi_{0,i'}^n(\xi')}{\eta_{n,i'} - \eta_{n,i'}^0 - \varepsilon_{n0}}] , \tag{16}
\]

where the special sign \( \oplus \) refers to the new, dynamically probabilistic meaning of the sum over realisations (implying their permanent probabilistic change, with the dynamic probabilities (12)-(13)), \( n \neq 0 \), \( \varphi_0(q) \), \( \varphi_n(q) \) are the known eigenfunctions of the e/m protofield Hamiltonian \( h_e(q) \) (see eqs. (4)), \( c_i^r \) are the state-function matching coefficients providing the rigorous derivation of the generalised Born rule (13) for realisation probabilities [1,5,6,8-12,14], and \( \{\psi_0^n(\xi), \eta^r\} \) is the set of the \( r \)-th realisation eigenfunctions and eigenvalues of the effective existence equation (8)-(9).
In accordance with the above physically transparent interpretation of the emerging protofield interaction result, it can be seen from eqs. (15)-(16) that due to the joint action of cutting integrals in numerators and resonant denominators each appearing $r$-th (regular) state-function realisation concentrates around one of its eigenvalues, $\eta'_r$, naturally interpreted as emerging physical space point and elementary particle “hard core” (or “virtual soliton”) [1,5,6,8-12,14]. This feature is self-consistently confirmed by a similar expression (9) for the effective potential, which will also show the highest magnitude of potential well of the same $r$-th realisation at $\eta = \eta'_r$. Permanent change of system realisations in causally random order, eq. (15), can therefore be specified as alternating protofield contractions (with their dynamic entanglement) and extensions (with disentanglement) around randomly chosen (but close enough) centres.

We call each such local, spatially chaotic and highly nonlinear self-oscillation process in the coupled protofield system quantum beat and show that it demonstrates all the observed physical properties of a (massive) elementary particle, now specified as an intrinsically dualistic field-particle, such as the electron [1-11]. Compound elementary particles, including essentially hadrons, contain several such variously coupled and mixed quantum beat processes (appearing e.g. as quarks). Different kinds of particles appear due to several possible global realisations of the EP magnitude, with stronger effective interaction between protofields for heavier particles (showing eventually stronger forces of interaction between them, see the next section). Massive localised field-particle emergence in the vast (practically “infinite”) system of coupled protofields leads to growing tension of protofield sections between the particles (giving rise to their interactions, see below), so that for a fixed protofield coupling magnitude new massive particles with sufficiently strong protofield interaction and entanglement within them cannot form any more, leaving only possibilities for much smaller, massless protofield perturbations in inter-particle spaces, such as photons (still representing, however, a coupled state of the two protofields, in the form of very weakly dissipative solitons, see the next section).

In that way we obtain the key features and general picture of the observed first level of complex-dynamical protofield interaction results, or the

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2 We assume here the suitable choice of e/m protofield eigenfunctions $\phi_0(q)$, $\phi_a(q)$ in eqs. (4) as narrow peaks describing the eigenstates of its real, though maybe irresolvable, components.
first (dynamic) complexity level of the world (further details and higher complexity levels are specified below), consistently derived from the unreduced protofield interaction analysis, without any additional assumptions, “models”, “principles”, or pre-existing structures, either explicit, or “hidden”, “dark”, “parallel”, etc. (as it is done in unitary theories). Two universal and deep distinctions of this and following results within our emerging and physically real world description from any unitary science model are that (1) all real-world structures are now obtained as essentially complex, dynamically multivalued interaction processes, and (2) any world structure or property is actually a manifestation, or feature, of interaction-driven, cause-and-effect dynamics, instead of the opposite dynamical features modelling by postulated, finally arbitrary, abstract-mathematical and fixed structures in the standard science framework. Various unitary hidden variables, in quantum mechanics and beyond, are now explicitly obtained in the form of plural system realisations, i.e. its real, dynamically emerging and always changing structures and regimes. Only the truly consistent, totally causal dynamical approach used here can (and naturally does) provide the genuine theory of everything, also beyond the limits of the currently empirically observable, today’s “material” reality [2].
Emerging complexity features at its lowest sublevels: Space, time, mass, interactions, and quantum relativity

We can now further specify the dynamically emerging properties of the obtained first and then higher complexity levels of the interaction-driven real world system. We start with the already mentioned fundamental entities of space and time, none of them assumed or implied in any way in the initial interaction problem formulation, eqs. (1)-(3). The emergence of local quantum beat (self-oscillation) processes in the initially homogeneous system of coupled protofields, rigorously derived above by the unreduced interaction analysis (eqs. (8)-(9), (15)-(16)), provides already the physically transparent concept and origin of space and time as being due to, respectively, inhomogeneous, highly nonlinear squeeze (reduction) of the entangled protofields within the corpuscular virtual soliton state of thus obtained elementary field-particle (alternating with the opposite protofield extension and disentanglement) and permanent change of the centre of each next quantum beat reduction in chaotic (dynamically random) order. While the fundamental physical space is the emerging tangible, “material” structure of entangled protofields, time is the accompanying nonmaterial, spatially chaotic process of interaction-driven realisation change, reduced to chaotic virtual-soliton wandering at this first complexity level. Whereas the emerging space structure is dynamically discrete due to the finite amplitude of protofield compression, the related time flow is intrinsically unstoppable and irreversible due to the unstoppable realisation change and their causally random order of appearance.

These basic features of emerging space and time can be specified in a mathematically rigorous (and actually universal) way [2,9-11,15-24,28], where the size $r_0$ of a physical point of emerging real space is determined by the characteristic eigenvalue separation within one realisation of the effective existence equation (8)-(9), $r_0 = \Delta x_i = \Delta r_i r$, while the elementary length $\Delta x = \lambda$ (the minimum distance between points) is determined by the eigenvalue separation between different (neighbouring) realisations, $\Delta x = \lambda = \Delta r_i r_i$. The elementary time interval $\Delta t$ is dynamically determined as
the quantum beat period $\tau$, $\Delta t = \tau = 1/\nu$, where $\nu$ is the quantum beat frequency, actually expressing the intensity of spatially chaotic realisation change.\(^3\) The $\Delta t$ value can be conveniently obtained from the above elementary length $\lambda$ and the velocity $v_0$ of perturbation propagation in the e/m protofield (coupled to the gravitational protofield), $\tau = \lambda/v_0$, where $v_0$ in this general expression is obviously identified at this lowest complexity level as the speed of light $c$, $\tau = \lambda/c$, because the e/m protofield excitations are observed as photons. Note that the intrinsic universality of the obtained space and time origin, qualities and definitions means that both entities can be defined for any higher complexity level, thus revealing their multilevel (and eventually dynamically fractal) structure naturally related to the emerging probabilistic fractal of the world complexity (see below).

We see that the first level of the world structure, in the form of elementary particles, space and time, is explicitly, dynamically created in the unified complex-dynamical (multivalued) process of quantum beat as a result of initially homogeneous interaction between the e/m and gravitational protofields. The emerging dynamically woven space and irreversibly flowing time constitute the elementary forms of dynamic complexity universally measured by a growing function of the number of consecutively taken system realisations, eqs. (14). It is not difficult to understand therefore that the fundamental integral measure of complexity is provided by action-complexity $A$ generalising the notion of usual mechanical action as the simplest linear combination of (growing) space and time [1,2,5,6,8-24,28]:

$$\Delta A = p\Delta x - E\Delta t,$$

(17)

where the coefficients $p$ and $E$ are recognised as (generalised) momentum and energy defined now as universal differential complexity measures (provided by spatial and temporal rates of realisation change respectively):

$$p = \left. \frac{\Delta A}{\Delta x} \right|_{t=\text{const}} = \frac{A_0}{\lambda},$$

(18)

\(^3\) Note the fundamental importance of dynamically random character of each time-creating event of realisation emergence in our universal definition of real time flow, here and below, reduced to causally random choice of each next emerging realisation from the entire set of really (and equally) possible, but incompatible (redundant) realisations [1,2,10,14,28]. Real time is intrinsically related to fundamental, causal unpredictability of its emergence events, and that’s exactly why it flows irreversibly. This crucially important link between time and genuine dynamic randomness does not even appear in any usual, dynamically single-valued theory, where the imitative unitary time-parameter is seen, on the contrary, as a result of regular (or arbitrary) sequence of predetermined, formal “events” (for example, in some recent versions of quantum gravity).
\[ E = -\frac{\Delta A}{\Delta t} \bigg|_{x = \text{const}} = \frac{A_0}{\tau}, \]  
\( \text{(19)} \)

with \( x \) and \( p \) understood in general as vectors and \( A_0 \) expressing the characteristic action magnitude.

At the considered first level of complexity, the general definition (19) of the total energy (of the quantum beat process, or elementary field-particle) takes the form [1,2,5-12,14]:

\[ E = -\frac{\Delta A}{\Delta t} \bigg|_{x = \text{const}} = \frac{h}{\tau} = hv, \]  
\( \text{(20)} \)

where the quantum beat period \( \tau = \Delta t \big|_{x = \text{const}} \) and frequency \( \nu = 1/\tau \) hint already on the intrinsic and *physically real wave-particle duality* of complex-dynamical origin, while the *Planck constant* \( h = \Delta A = A_0 \) is now *rigorously derived* as the characteristic change and value of *action-complexity* remaining *discrete* (due to realisation discreteness) but also *fixed* and *universal* at this *lowest* complexity level (see also below, after eq. (42)).

We can now introduce the rigorous universal definition of the *state of rest* of any system as the one with the smallest dynamic complexity (specified as energy and always positive), while a *state of motion* is rigorously defined as any system state with energy-complexity above the minimum value of the state of rest. While these definitions do not depend on any intuitive ideas and empirical measurements, it follows from eq. (17) that the generalised momentum-complexity in the state of rest is absent, \( p = 0 \). The (state of) *rest energy*, \( E_0 \), of the elementary field-particle (quantum beat) is specified from eq. (20) as:

\[ E_0 = \frac{h}{\tau_0} = hv_0, \]  
\( \text{(21)} \)

coinciding with the famous suggestion by Louis de Broglie [46-49], now with the clearly understood, complex-dynamic origin of his postulated “periodic phenomenon” within the particle (our quantum beat process). In particular, in our description we deal with the *spatially chaotic* quantum beat pulsation equivalent to *chaotic wandering* of the squeezed corpuscular state of virtual soliton, which provides the total field-particle energy (the rest energy in (21)) with the intrinsic complex-dynamic property of *inertia*, thus properly completing another intuitively introduced de Broglie’s idea, that of the “*hidden thermodynamics*” of the isolated particle [50-52].
In order to obtain the rigorous expression of inertia within intrinsic unification of quantum-mechanical and relativistic properties, we return to the general case of a moving field-particle, whose action-complexity contains space inhomogeneity due to the self-organised tendency of global motion in realisation probability distribution, \( \mathcal{A} = \mathcal{A}(x,t) \), so that eq. (17) can be presented in the differential form as

\[
\frac{\Delta \mathcal{A}}{\Delta t} = \left. \frac{\Delta \mathcal{A}}{\Delta t} \right|_{x = \text{const}} + \left. \frac{\Delta \mathcal{A}}{\Delta x} \right|_{t = \text{const}} \frac{\Delta x}{\Delta t} = p \nu - E,
\]

or

\[
E = -\frac{\Delta \mathcal{A}}{\Delta t} + p \nu = \frac{h}{T} + \frac{h}{\lambda} \nu = hN + p \nu,
\]

(22)

where the total energy \( E \) is given by (20), while the global motion momentum \( p \), universally defined by eq. (19), is specified for the field-particle as

\[
p = \left. \frac{\Delta \mathcal{A}}{\Delta x} \right|_{t = \text{const}} = \frac{h}{\lambda},
\]

(23)

\( \nu \) is the global motion velocity,

\[
\nu = \frac{\Delta x}{\Delta t},
\]

(24)

\( \tau = \Delta t\big|_{x = \text{const}} \) is the period of quantum beat (virtual-soliton realisation change) measured at a fixed space point, \( \lambda = \Delta x\big|_{t = \text{const}} \) is the size of emerging spatial inhomogeneity of the average, global part of the moving system structure at a fixed time moment, and \( \Delta t = T \) is the “total” value of the quantum beat period ( \( N = 1/T \) is the corresponding frequency) [1,2,5,6,8-12,14].

The total energy partition of the moving field-particle, eq. (22), has a deep physical, complex-dynamical meaning: its first summand, \( hN = h/T \), describes purely random wandering of the virtual soliton around the ordered average tendency of global motion described by the second summand, \( p \nu = h \nu / \lambda \). This last tendency of global motion contains the dynamically emerging spatial structure with the characteristic length \( \lambda \), easily recognised as the particle’s de Broglie wavelength, \( \lambda = \lambda_B = h/p \), appearing thus quite naturally, together with the physically real wave-particle duality, in the

\[\text{Note, however, that each virtual soliton leap, even within this “generally ordered” tendency, has a dynamically probabilistic origin, with (slightly) higher probability of staying in this global motion tendency, than deviating towards the purely random wandering tendency (the first summand in eq. (22)), in accordance with the general definition of dynamic realisation probabilities for compound, or “self-organised”, realisations, eq. (12b). This fact is fundamentally important for (relativistic) mass involvement in quantum field-particle dynamics (see below).}\]
multivalued quantum beat dynamics as a result of partial regularity of the global motion tendency [1,2,5,6,8-12,14]. This physically real duality means, as we have seen above and shall see below, that all quantum processes and interactions include as important underlying basis permanent, physically real quantum leaps of participating field-particles, with their real transformation between the corpuscular localised state of virtual soliton and the extended transient state of (physically real) wavefunction.

We can see now the physically transparent, causal origin of the “relativistic” limitation, \( v < c \), introduced in usual relativity as a formal postulate: every massive particle (and thus eventually any material body) always moves globally, as a whole with a speed smaller than the perturbation propagation speed in the e/m protofield coupled to the gravitational protofield, \( v_0 = c \), simply because the virtual soliton of its complex-dynamical quantum beat process must make many random deviations from the average global motion trajectory (while massless perturbations, such as photons, move with \( v_0 = c \) by definition). As a matter of fact, all usual global motions of massive matter occur at “nonrelativistic” velocities \( v \ll c \), meaning that virtual soliton leaps within the second-summand tendency of global motion in the total energy partition (22) constitute only a small proportion of the total energy-complexity (it is shown in detail below), while almost all particle’s energy is spent on random deviations from the global motion tendency. It is a physically meaningful feature as it implies the well-formed and reasonably stable usual-world structures, while a relativistic situation with \( v \rightarrow c \) corresponds to ephemeral and changeable structures tending eventually to massive, strong-interaction “photons”.

These details of complex internal dynamics of a massive particle lead to the important quantitative relation between \( v \) and \( c \). We note that during the time interval \( \tau_1 = \lambda/c \) of one virtual soliton leap within the global motion tendency the same quantum beat system performs \( n_1 = c/v \) leaps of purely random deviations from the global tendency of duration \( \tau \) each (where \( \tau \) is defined in eq. (20)). Hence \( \tau_1 = n_1 \tau \), or \( \lambda = V_{ph} \tau \), where \( V_{ph} = c^2/v \) is the fictitious superluminal “phase velocity” of matter wave propagation, appearing in the original derivation of de Broglie wavelength [49], which does not take into account the dominating chaotic, multivalued part and character of field-particle dynamics. Inserting the definitions of \( \lambda \) and \( \tau \), eqs. (23) and (20), into the obtained relation, we get the famous relativistic dispersion relation,
now rigorously derived from the underlying complex quantum beat dynamics (as opposed to the canonical relativistic postulates):

\[ p = E \frac{v}{c^2} = mv, \]

where the inertial mass-energy-complexity, \( m \), is introduced by a rigorously substantiated and physically meaningful definition [6-12]:

\[ m = \frac{E}{c^2}. \]

Expressions (21) and (20) for the total energy-complexity of spatially chaotic quantum beat pulsation in the states of rest and motion take now their physically complete form:

\[ E_0 = m_0 c^2 = \hbar \nu_0 = \frac{h}{\tau_0}, \]

\[ E = mc^2 = \hbar \nu = \frac{h}{\tau}. \]

We obtain thus the rigorously derived and universally valid concept of inertial mass (in its naturally emerging relativistic version equivalent to energy) as a differential complexity measure by the temporal rate of the spatially chaotic quantum beat (realisation change) dynamics within every elementary field-particle (and thus any compound particle or body), which does not need usual artificial introduction of additional, actually redundant entities as the “source of mass” (such as the purely abstract construction of the Higgs field and bosons in the Standard Model of official particle physics, showing a number of irreducible fundamental deficiencies and contradictions [11,12]). We also show (see below) that this concept of complex-dynamical mass naturally includes its (relativistic) gravitational aspect. These results demonstrate the dynamically emerging and naturally unified character of fundamental dynamic and intrinsic properties (like space, time and mass) in our approach, as opposed to their postulated, abstract and separated origins in usual, unitary theories. We complete below the number of fundamental properties thus causally explained within the same unified analysis of unreduced proto-field interaction process. Note also equally naturally emerging unity of quantum and relativistic properties as different but unified manifestations of the same complex interaction dynamics (we further specify it below). This unity is persistently missing in usual theory for the now evident reason of its artificial single-valued simplification of real, multivalued interaction dynamics.
Another remarkable feature of our complex-dynamical mass concept (25)-(26) is the usually postulated but now rigorously derived relation $p = mv$ equivalent to *rigorously derived Newton’s laws of motion* (in their causal relativistic and actually quantum version) and hiding behind its externally simple form the nontrivial complex (multivalued) dynamics of the underlying protofield interaction process [6-12]. All the *emerging* notions, including that of motion itself, its laws, the entities of space, time, energy, momentum, and mass acquire now their genuine, intrinsically unified and causally complete complex-dynamical meaning and origin, where “quantum” (dynamically discrete and dualistic) and “relativistic” (dynamically driven) features are naturally unified from the beginning.

Inserting now the obtained dispersion relation (25) into the causal definition of the field-particle wavelength (23), we get the complete canonical expression for the *de Broglie wavelength of a massive particle* within the causally complete complex-dynamical picture of wave-particle duality:

$$\lambda = \lambda_B = \frac{h}{mv} , \tag{29}$$

or $h = mv\lambda_B$, where the Planck constant $h$ represents “protofield interaction complexity dynamically quantised in action-complexity units of $h$”, field-particle mass $m$ measures “dynamic complexity of causally random virtual soliton wandering within the particle wavefield”, $v$ is the speed of global particle (quantum beat) motion, and $\lambda_B$ is the “dynamically emerging undular structure of the globally moving quantum beat process” [7]. The dynamically multivalued and deeply nonlinear character of externally simple and linear expression (29) (and other related wave formalism equations) becomes evident and provides the causally complete origin of “wave-particle duality” and other “quantum mysteries” [6-12] (see also below).

In the state of rest, we have only dynamically random virtual soliton leaps within its globally motionless wavefield, each of them performed with the speed of light $c$. The size of each leap, representing the above elementary length $\lambda = \Delta x_r$ at this lowest complexity level, can be specified either by the “heuristic” application of eq. (29) to a single virtual soliton leap or, more rigorously, by noting that the quantum beat frequency $\nu_0 = m_0 c^2 / h$ from eq. (27) corresponds to the wavelength

$$\lambda_0 = \frac{c}{\nu_0} = \frac{h}{m_0 c} . \tag{30}$$
For the electron with the rest mass \( m_0 = m_e \) the size \( \lambda_0 \) of virtual soliton leap within the quantum beat process coincides with the Compton wavelength \( \lambda_C \) (up to a factor of the order of \( \pi \), see below), providing its new interpretation in terms of \textit{complex electron dynamics}:

\[
\lambda_C = \frac{\hbar}{m_e c} .
\] (31)

The emerging dynamically discrete, or \textit{quantised}, undular structure of the field-particle naturally coexists with the equally dynamically emerging \textit{relativity} of multivalued interaction dynamics. Since physically real time dynamically emerges within the same complex-dynamical process that gives rise to global motion, eqs. (20), (27), this motion will influence the real time flow. To specify that causally explained, complex-dynamical time relativity, we use eqs. (20) and (25) (the dynamically derived relativistic dispersion relation) in the energy partition equation (22) and obtain the \textit{causal time dilation effect} as the relation between the externally and internally measured time periods (of quantum beat) \( \tau \) and \( T \) for a moving particle:

\[
\tau = T \left(1 - \frac{v^2}{c^2}\right) .
\] (32)

The physical meaning of this relation in terms of the underlying complex quantum beat dynamics is that with growing speed of global motion \( v \) ever larger part of the total energy goes from the “internal clock mechanism” to its global displacement, thus leading to relative slowing down of the internal time flow, \( T > \tau \). The effect is universal and does not depend on the size and mechanism of any real time-measuring system, thus solving another persisting puzzle of usual relativity.

The causal quantum-relativistic time dilation effect of eq. (32) needs further refinement in terms of quantum beat period in the rest frame \( \tau_0 \) (or its frequency \( \nu_0 = 1/\tau_0 \)), which is related to \( T, \tau \) (or \( N, \nu \)) [1,5,6,8-12]:

\[
N\nu = (\nu_0)^2, \; T\tau = (\tau_0)^2 .
\] (33)

This relation describes the physically transparent conservation of the system realisation number expressed by frequencies in any reference frame, which is a manifestation of the universal complexity conservation law (see below). We use eq. (33) to eliminate not directly measurable \( \tau \) from eq. (32) and obtain the canonical expression for the time dilation effect, now however \textit{causally substantiated} by the underlying complex interaction dynamics,
without any postulated abstract “principles”:

\[ T = \frac{\tau_0}{\sqrt{1 - \frac{v^2}{c^2}}}, \quad N = v_0 \sqrt{1 - \frac{v^2}{c^2}}. \]  

(34)

Using eqs. (27), (28) in combination with time dilation expression (34), we obtain the \textit{causally derived} effect of \textit{relativistic mass increase} emphasizing the role of dynamically random origin of every quantum beat leap of a massive field-particle, even within the externally regular global motion tendency:

\[ m = \frac{E}{c^2} = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}. \]  

(35)

Relativistic length transformation expression is also easily obtained from time dilation (34), thus completing our causal, complex-dynamical special relativity intrinsically unified with quantum behaviour [1,5,6,8-12].

We can now provide the detailed version of the complex-dynamical energy partition (22) demonstrating the unified origin of relativistic and quantum features and showing the proportions of global motion and random deviation tendencies depending on the particle/body global motion speed \( v \):

\[ E = h\nu_0 \sqrt{1 - \frac{v^2}{c^2}} + \frac{h}{\lambda_B} v = h\nu_0 \sqrt{1 - \frac{v^2}{c^2}} + h\nu_B = m_0 c^2 \sqrt{1 - \frac{v^2}{c^2}} + \frac{m_0 v^2}{\sqrt{1 - \frac{v^2}{c^2}}}, \]

(36)

where we have introduced de Broglie frequency, \( \nu_B \), according to

\[ \nu_B = \frac{v}{\lambda_B} = \frac{p v}{\hbar} = \frac{\nu_{B0}}{\sqrt{1 - \frac{v^2}{c^2}}}, \quad \nu_{B0} = \frac{m_0 v^2}{\hbar} = \nu_0 \frac{v^2}{c^2} = \nu, \quad \lambda_B = \frac{h}{m_0 v}. \]  

(37)

It is not difficult to see [5,8,10] that \( \alpha_1 = \nu^2/c^2 \) and \( \alpha_2 = 1 - \alpha_1 = 1 - \nu^2/c^2 \) are the probabilities for the field-particle’s virtual soliton to fall within the global-motion and random-deviation tendencies respectively, in accordance with the universal realisation probability expression of eq. (12b), which demonstrates once again the deep complex-dynamical link between “quantum” and “relativistic” aspects of the unreduced protofield interaction result. Usual, nonrelativistic global motions are mainly irregular, \( \alpha_1 \ll \alpha_2 \approx 1 \), due to the dominating rest mass chaoticity, while relativistic and ultra-relativistic
motions are ever more internally ordered as $v \rightarrow c$, $\alpha_2 \ll \alpha_1 \approx 1$, which explains, in particular, the well-defined swift-particle trajectories.

Let us consider now the equally dynamically emerging character of intrinsic global properties of the world, such as the origin and the number of spatial dimensions and fundamental interaction forces. The observed number of spatial dimensions, $N_{\text{dim}} = 3$, is causally explained in our picture as the number of global system realisations equal to the number of global interacting degrees of freedom (in our case two protofields plus their uniform coupling). In general, a universe emerging from $n$ protofields coupled by $m$ global (universal) interactions should have at least $N_{\text{dim}} = n + m$ global spatial dimensions. Depending on the protofield interaction details, the number of spatial dimensions may be given by another (growing) function $N_{\text{dim}}(n,m)$ [1], but in each case there is the exact correspondence between the number of interacting global fields and the emerging number of spatial dimensions, since the latter are none other than the dynamically entangled states (realisations) of those global interacting entities. This causal origin of emerging physical space and its dimensions is very different from formal constructions of usual theory, where one can add various fields (such as the Higgs field) or “hidden dimensions”, replacing the dynamic origin of intrinsic entities and properties, irrespective of the observed number of spatial dimensions.

The same kind of well-defined causal connection explains the observed number of fundamental forces between elementary field-particles, together with their transparent physical origin and properties. As each massive field-particle produces essential (propagating) deformation and tension in the surrounding protofield material due to its highly nonlinear quantum beat pulsation, other particles’ quantum beat processes “feel” these changes, both in the form of direct mechanical attraction/repulsion and average, “entropic” (i.e. chaotically structured) change of properties. This is the physical origin of (maximum) $mn$ long-range particle interaction forces of $n$ different types (each type being transmitted through its own protofield). In the real simplest case of two interacting protofields ($n = 2$) with a single coupling ($m = 1$) we obtain long-range e/m and gravitational interactions (2 interactions of 2 types), explaining the names and roles of respective protofields. Due to the described physical transmission mechanism, their inverse-square spatial dependence, $r^{-2}$, is obviously determined by the causally derived number of spatial dimensions (it will be $r^{1-N_{\text{dim}}}$ in the general case).
Short-range interactions are due to those between the protofield elements (within each protofield) and their minimum number is equal to \( n \) (as well as the number of their different types, each for its own protofield), with one “weak interaction” (within the e/m protofield) and one “strong interaction” (within the gravitational protofield) for the two interacting protofields in our real world construction. We thus immediately obtain a general idea of the physical origin and properties of the gravitational protofield as a kind of “quark(-gluon) condensate”, where “individual” quarks may exist rather in the form of quantised excitations of a strong-interaction “liquid” condensate (in accord with recent experimental results for high-energy ion collisions [53], looking “surprising” in the framework of usual formal theory). This physically specified origin of quarks in the unified, interaction-driven world construction correlates well with their very special property of confinement, “explained” in usual theory in a quite contradictory way using largely unphysical assumptions. In reality those quark excitations of the quark-gluon condensate of the gravitational protofield matrix cannot appear individually not only due to their strong interaction with other, equally ill-defined quarks (which is a finite and thus surmountable barrier) but also because of the omnipresent “close” reservoir of strong-interacting “quark matter” that must provide some accompanying partners once the excitation energy exceeds the mass-energy interaction threshold. The observed quasi-stable quark combinations within hadrons are the smallest stable quanta, or “droplets”, of the underlying quark-gluon “liquid”, for which the internal binding forces (supported by the protofield interaction) can overbalance the separating influences of the surrounding liquid (protofield) volume.

In this way we obtain the exactly defined total number of \( N_F = n(m+1) \) emergent fundamental interaction forces between elementary particles of well-specified physical origin and qualities, giving the observed number of four interactions with their observed properties for our (simplest kind of) world emerging from two interacting protofields. We see again that the world’s fundamental forces, fields and dimensions appear in exact, well specified numbers, qualities and relations to each other (e.g. \( N_F = n(N_{\text{dim}} - n + 1) = (m+1)(N_{\text{dim}} - m) = 2(N_{\text{dim}} - 1) \), the last equality specified for our world with \( m = 1 \)), so that it is impossible to introduce an additional global field, such as the Higgs field, while preserving the same number of dimensions and interaction forces (as it is done in usual theory, in various versions, including
equally redundant “hidden dimensions” or “dark-matter” particles, these cosmological “hidden variables” of unitary science). It is the concrete and essential difference between any conventional, unitary theory construction and the dynamically complete, emergent and therefore naturally “parsimonious” physical structure of the world in our interaction-based approach.

In relation to this feature, all the emerging structures and properties in our picture, including interaction forces, appear in their intrinsically, dynamically unified version, so definitely lacking in the Standard Model constructions (or any other versions of unitary description). All four (in general \( n(m+1) \)) interaction forces are naturally unified by their dynamic origin, the quantum beat process within any massive elementary particle (meaning also that they are naturally quantised from the beginning), with the most direct and complete unification in the maximum squeeze state of virtual soliton for hadrons. This general unification is subdivided into two (in general \( n \)) closer, “material” unifications between two (in general \( m+1 \)) forces transmitted by the same protofield, one of them of short-range origin (from interaction between the protofield elements) and another one (in general maximum \( m \)) of long-range, deformation/depletion origin.

The standard, formally introduced “electroweak symmetry” acquires now the physically transparent origin and dynamics in terms of “material” unification of interactions by the e/m protofield. In particular, the “electroweak scale” of energy describes now simply the energetic “strength” of the e/m protofield (i.e. the binding energy of its elements or the highest nondestructive excitation energy), which naturally coincides, due to the general quantum-beat unification, with the heaviest particle (or nucleus) mass, \( M_p \sim 10^2 \text{ GeV} \) (cf. eq. (27)), without any additional “Higgs field” involvement or related “hierarchy problem” (see also below).5

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5 Let us emphasize the causally explained coincidence between the heaviest elementary particle mass scale and that of the heaviest nuclei (both of the order of 100 GeV), up to uncertainty due to instability effects. It becomes clear only within our causally unified picture why it should be like that: the strong internal interaction between hadrons (actually quarks) in any “compact agglomerate” of excited quark-gluon matter of the coupled protofields, be it a nucleus or an elementary particle, means that the largest possible mass of any such dynamically unified real object will be determined by the total strength of the coupled protofields, actually of the order of 100 GeV. It not only demonstrates the remarkable unification degree of our theory (including all fundamental interactions, their natural couples, and all real “coherent” species of strongly interacting particles), but also reveals practical senselessness of further search for ever heavier elementary particles and chemical elements (in accord with the related hierarchy problem solution, see below), which otherwise still goes on, blindly, without basic limits, in the official theory paradigm [6,11,12].
Another case of “material” unification, involving the gravitational protofield, is even more interesting as it introduces the *gravi-strong unification and symmetry* between the gravitational and strong interactions, totally unknown in any usual theory (in relation to its general hard problems with gravity, its true origin and quantisation). Our *dynamically emerging* gravity, transmitted by a dense “quark-gluon matter”, provides a suitably compact and problem-solving construction, with natural, dynamic quantisation at its very origin, but absent conventional “gravitons” and improbable long-distance “gravitational waves” (see also below) [1,2,5,6-12].

The mentioned *natural quantisation* of long-range interaction forces due to their quantum-beat origin clarifies also another ambiguous idea of conventional theory, that of “exchange”, or “gauge”, or “virtual” bosons “transmitting” the quantised (in practice usually electromagnetic) interaction. Their inevitably “virtual” status in usual theory is now extended to that of quite real excitations (photons for e/m interactions), which inevitably appear as a result of interacting quantum beat dynamics (even though the gravitational protofield exchange bosons, or “gravitons”, are not well-defined excitations due to their rapid decay in this dense, strong-interaction “liquid”).

In general, those causal “exchange bosons”, such as photons, appear in our description as real (protofield) excitations and not as an abstract result of mathematical “gauge symmetry” (where they are called “gauge bosons”) that needs further introduction of additional, “symmetry-breaking” Higgs field leading to deep contradictions [11,12]. Those strangely “broken” (but nevertheless real) “symmetries” of usual unitary theory, giving rise to redundant abstract entities, are replaced in our provably parsimonious, “Ockham-friendly” description by the *universal and exact*, never broken symmetry (*or conservation by transformation* of complexity), describing real structure formation within any unreduced, multivalued interaction process (see below).

To conclude this general overview of the lowest, “quantum” sublevels of emergent complex-dynamical world structure, we note that it is definitely

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6 The above physically real “gravi-strong unification” of gravitational and strong interactions through the gravitational protofield implies, in particular, that if gravitons could be stable enough, they would be realised as suitable combinations of gluons. Quarks cannot be present in these combinations because gravitons should be massless particles, which is an additional source of doubt about their reality, taking into account the dense, strong-interacting mixture of gluons and quarks within the gravitational protofield. In a way, gluons may be related to other exchange bosons, those observed as photons, if the e/m protofield originates as an excited state of gluon components of the primordial common origin of protofields, the true ground state of the quark-gluon condensate (see also the next section).
displaced, in the result of the driving protofield interaction, from the gravitational to the e/m protofield, where the majority of actually observed structures are made of the much more deformable and elastic material of the latter, while the former plays the equally important role of a much less changeable “supporting matrix” of the world, ensuring the proper dynamic stability of the entire strongly asymmetric construction. This is also the ultimate reason for the “mysterious” relative weakness of gravity, involving the natural solution to the “mass hierarchy problem” (see below).

We proceed by further specifying the causal, dynamically unified origin of intrinsic particle and interaction properties, which are simply postulated as separated abstract quantities in usual theory. On the electromagnetic, explicitly observable side of the world, we obtain the main e/m feature of electric charge of an elementary field-particle as just another manifestation of the same, complex quantum beat dynamics, reflecting its properties of e/m interaction through the e/m protofield and actually representing yet another measure of universal dynamic complexity. This properly understood dynamic origin of electric charge in quantum beat pulsation as its complexity measure is supported by the well-known proportionality relation between the elementary electric charge $e$ and the fundamental dynamic complexity quantum in action units, the (reduced) Planck constant $\hbar = h/2\pi$ (see eqs. (21), (27)), $e^2 = \alpha c \hbar$, where $\alpha$ is the fine-structure constant. In such interpretation of this relation, it explains the electric charge quantisation and universality of its quantum by respective properties of the first levels of world’s interaction complexity (in terms of $\hbar$), naturally unified with the dynamically discrete structure of material reality in general (in “quanta” of massive elementary particles). While some other particle properties, such as mass, can vary from one particle to another, the quanta of electric charge and action-complexity apply everywhere and remain fixed as reflecting the unchanged mechanical features of the underlying e/m protofield coupled to the gravitational protofield (see also below). The charge conservation law, only postulated in usual theory, emerges now as a corollary to the rigorously substantiated universal symmetry of complexity (similar to mass-energy conservation and other fundamental laws and principles [1,2,28]).

Because of the direct mechanical character of e/m interaction between quantum beat processes, the e/m interaction force will depend on relative phases of quantum beat oscillations, so that with arbitrary relations between
phases, we would observe considerable uncertainty or fluctuations of e/m interaction between individual elementary particles, with further destructive consequences for higher, atomic and molecular structures and processes. On the other hand, as quantum beat pulsation determines the physically real time flow (see above, eq. (27)), its phase relations for different particles cannot vary either, in order to ensure the suitably “smooth” (coherent) time flow everywhere in the universe, tacitly underlying the totality of world descriptions and observations. These considerations lead to the only possible conclusion about the universal phase synchronisation between quantum beat oscillations of all field-particles (within “our” known and highly structured Universe), up to phase inversion [1,2,5,6,8-12,14]. Indeed, in this case we obtain not only the properly ordered e/m interaction forces and coherent time flow but also exactly two, “opposite” kinds of electric charge for field-particles with opposite in phase but otherwise synchronous quantum beat oscillations (where particles with the same kind of charge will, similar to antagonistic competitors, repel each other, while the oppositely charged, antiphase field-particles will “collaboratively” attract each other). It means that there is one, “fundamental”, or “ground-state”, quantum beat frequency (probably that of the electron, $\nu_e = m_e c^2 / h = 10^{20} \text{Hz}$ ) common to all electrically charged elementary particles throughout the universe, pulsating thus in phase or antiphase, while all higher quantum beat frequencies for heavier charged particles (in particular hadrons) are due to local high-frequency super-structures of the ground state pulsation. Thus introduced universal temporal phase synchronisation ensures also the possibility of quantum-wave spatial coherence in many-particle systems, which otherwise would hardly be compatible with globally ordered structures and dynamic processes and provides a local mechanism of global phase synchronisation establishment.

Another intrinsic field-particle property, remaining only formally postulated but physically unexplained within the usual theory framework, is elementary particle’s spin. While, as we have seen, particle’s electric charge is due to quantum beat oscillatory motion, the dynamic origin of spin is provided by another, rotational component of the same quantum beat pulsation, in the form of highly nonlinear vorticity of the e/m protofield increasingly squeezed towards its corpuscular state of virtual soliton. Similar to the dynamics of fluid forced to pass through a narrow outlet, it is eventually due to shear instability of the moving protofield matter. The causally substantiated
de Broglie relation for the field-particle rest energy, eq. (21), can now be rewritten as \( E_0 = h\nu_0 = \hbar\omega_0 = h\nu_0/2 + s\omega_0 \), where \( \omega_0 = 2\pi\nu_0 \) is the quantum beat circular frequency, while \( s = h/2 \) is the observed “anomalous” angular momentum of elementary spin (for the simplest fermion case). Note that the quantum beat oscillatory energy, \( E_0/2 = \hbar\omega_0/2 \), also coincides remarkably with the basic quantum expression for the oscillator ground state energy.

This dynamic origin of spin, deeply unified with those of electric charge and mass, provides not only the causally complete explanation for the observed spin properties (magnitude, quantisation, interactions and relation to the Planck constant) but also the unified causal origin of magnetic field as being due to the same spin vorticity (macroscopically, for many similarly oriented field-particle spins), rather in the extended phase of quantum beat pulsation. We obtain also the ultimate, physically complete origin of the laws of electrodynamics for thus explained magnetic and electric fields and charges [1], confirming the totally emergent character of all world structures, properties and laws in our description.

The other, gravitational protofield side of the same quantum beat processes within elementary field-particles gives rise, as noted above, to the second universal long-range interaction, gravity. Because of only indirect interaction transmission through highly dispersive gravitational protofield medium, no quantum beat phase synchronisation or real exchange-boson mechanism can be important for gravitational interaction, which leads to absence of different kinds of “gravitational charge” and only one, attractive kind of force. As gravitational field deformations are roughly proportional to quantum beat frequencies (at least for relatively weak, “nonrelativistic” gravitational interactions), the role of “gravitational charge” is played by inertial mass (or, in general, by its growing function), in accord with eqs. (27), (28), providing the causal explanation for the “principle of equivalence” of gravitational and inertial aspects of mass, which is only formally postulated in usual general relativity and absent from the Higgs mechanism of inertia.

Since our emergent gravity is explicitly driven by naturally quantised quantum beat processes, which both determine the time flow and modify the gravitational protofield density, one easily obtains the dynamically quantised general relativity effects [1,2,5,6,8-12,14], without any conventional postulates about “curved (abstract) space-time” and persisting ruptures between quantum and relativistic features (which are instead intrinsically unified in
our description as different manifestations of the same dynamic complexity of unreduced interaction processes). As the gravitational protofield density becomes inhomogeneous in the presence of quantum beat processes of massive particles and bodies, eq. (28) for the mass-energy-complexity of any (test) field-particle takes the generalised, coordinate-dependent form:

\[ M(x)c^2 = h\nu(x) = mc^2\sqrt{g_{00}(x)}, \]

where \( \nu(x) \) is the local particle quantum beat frequency (determining the local causal rate of time flow), \( M(x) \) is its total mass, \( m \) its relativistic mass in the absence of gravitational field (i.e. other bodies), and usual theory’s “metric” \( g_{00}(x) < 1 \) actually describes spatial distribution of the gravitational protofield density/tension. Since for weak fields \( g_{00}(x) = 1 + 2\phi_g(x)/c^2 \), where \( \phi_g(x) < 0 \) is the gravitational field potential [54], eq. (38) describes the causally derived, physically real origin of time dilation in gravitational field (as opposed to formal postulates about geometric “curvature” of arbitrary “mixture” of abstract space and time in usual theory), where both time and mass-energy (as well as space, through e.g. (23), (25), (29)) are now permanently and intrinsically quantised from the beginning.\(^7\)

Thus rigorously derived effects of emerging special and general relativity are naturally unified with quantum effects by their common origin in complex (multivalued) interaction dynamics, while they differ mainly by relative observation scale: a global, fine-grained observation scale reveals rather the smooth relativistic dependence of intrinsic features on dynamics, while

\(^7\) While the famous “Einstein field equations” of standard general relativity (actually involving “space-time curvature” in their canonical version) are obtained as formal mathematical generalisation of physical relations like eq. (38), it is not evident that such generalisation is as universally valid as usually assumed in the scholar science framework. In particular, they predict gravitational waves, which could hardly propagate over any sensible distances because of spreading and dispersion effects within the dense quark-gluon condensate of the gravitational protofield (despite their alleged, but very contradictory recent “registration”). This is only one particular illustration of fundamental limitations of Einstein’s equations due to their total neglect of the underlying complex interaction dynamics within the gravitational protofield and its coupling to the directly observable interface of e/m protofield (while they do pretend to a quasi-complete description of gravity, contrary to much more limited and averaged particular relations like eq. (38) or Newton’s theory). Another well-known problem is the fundamental contradiction between conventional relativity (including Einstein’s equations) and quantisation, which, as we have seen, is also due to the dynamic single-valuedness of usual theory neglecting complex dynamics of underlying real interaction processes. In terms of mathematics, one can say that the symmetries of usual general relativity are too simplified with respect to the universal symmetry of complexity, the genuine, never broken symmetry of nature [1,2,28]. Therefore, it would be wiser not to advance too quickly to the ultimate Einsteinian, global-geometric generalisation of particular relativistic gravitational effects, which might eventually have a much more involved, if ever any compact, expression in terms of universal dynamic complexity equations.
coarse-grained, small and therefore strongly inhomogeneous scales demonstrate the detailed quantum origin and structure of that relativistic reality emerging in unreduced interaction processes. It is not surprising therefore that these “relativistic” and “quantum” manifestations of complex interaction dynamics are universal for all complexity levels and reappear with growing interaction complexity, up to conscious cognition processes, including respective special and general relativity effects [1,2,10,14,27]. Needless to say, that universal complex-dynamic relativity effects cannot be revealed in standard, unitary quantum mechanics and relativity, which provide not the causal, physically real origin but only formally “guessed”, purely abstract postulation of quantum and relativistic features, despite the realistic preferences of the new-physics’ fathers (including Max Planck, Louis de Broglie and Erwin Schrödinger) [7].

The obtained dynamically unified origin of emerging fundamental forces, space and time entities, elementary particle structure, intrinsic properties, and fundamental constants has further extensions from both gravitational and e/m protofield aspects. Gravitational aspects involve the well-known problem of elementary particle mass hierarchy (revealing also the actual absence of causal mass spectrum origin and structure in usual theories and their ongoing accelerator applications) and the related too extreme values of conventional Planck units (extensively used nonetheless in various foundational schemes of usual theory, including inflation cosmology, quantum gravity, string theory, and practically entire particle and high-energy physics). Indeed, while the observed particle mass-energy spectrum extends up to the order of $m_{\text{exp}}c^2 \approx 100 \text{ GeV}$ (for exotic species and directly unobservable quarks), a “natural” combination of fundamental constants emerging in various estimates, the Planck mass $m_p = \sqrt{\hbar c / \gamma}$ (where $\gamma$ is the gravitational constant), gives a very different limiting mass-energy scale, $m_p c^2 \approx 10^{19} \text{ GeV}$ (this hierarchy problem can be expressed also as inexplicably huge relative weakness of gravity with respect to electro-weak interactions). Whereas the unphysically huge gap of 17 orders between $m_{\text{exp}}$ and $m_p$ (and between the respective units of length, $l_p \ll l_{\text{exp}}$, and time, $t_p \ll t_{\text{exp}}$) is tentatively attributed in usual theory to arbitrarily introduced additional entities of e.g. “supersymmetric” solutions or strangely “hidden” (and never experimentally confirmed) dimensions in the brane world construction [55] (a kind of rough mechanistic imitation of our interacting protofield picture), it does not even
appear in our picture of naturally unified interactions, just due to their dynamic unification within the quantum beat process, leading to the *modified values of Planck units* [1,2,6,8-12].

Indeed, since all interaction forces (expressed by respective fundamental constants) are dynamically unified within the virtual soliton state of maximum compression of both protofields, it becomes evident that the “gravitational constant” in expressions for Planck units actually refers rather to a *short-range*, more strong (quark-gluon), than gravitational interaction between the system components (within a dynamic mixture of usually separated interaction forces), while the usual, macroscopic gravitational constant $\gamma$, always used in conventional Planck units ($m_p$, $l_p$, $t_p$), describes a very different, *long-range* and *indirect* interaction kind between well separated e/m protofield features by weak transmission between uncompressed, extended protofields and long-range propagation through the gravitational protofield. If the latter, usual (long-range) gravitational constant is designated as $\gamma$, then the correct, *modified* expressions for Planck units should contain a much larger, short-range, unified “gravi-strong” interaction constant $\gamma_0 \gg \gamma$, determined by the actually observed largest mass-energy ($m_{exp} c^2 \simeq 100$ GeV) and smallest length ($l_{exp}$) and time ($t_{exp}$) scales as being close to real, modified Planck values of respective quantities ($M_p$, $L_p$, $T_p$):

$$M_p = \sqrt{\frac{hc}{\gamma_0}} \simeq 10^{-22} - 10^{-21} \, \text{g} \left(10^2 - 10^3 \, \text{GeV}\right) = m_{exp} \, ,$$

$$L_p = \sqrt{\frac{\gamma_0 h}{c^3}} \simeq 10^{-17} - 10^{-16} \, \text{cm} = l_{exp} \, ,$$

$$T_p = \sqrt{\frac{\gamma_0 h}{c^5}} \simeq 10^{-27} - 10^{-26} \, \text{s} = t_{exp} \, ,$$

with

$$\gamma_0 = \left(\frac{m_p}{m_{exp}}\right)^2 \gamma \simeq (10^{33} - 10^{34})\gamma \, .$$

The latter relation provides thus the natural solution to the “hierarchy problem” of usual theory, demonstrating the real physical origin of properly modified Planck units, the general, causally determined scale of the observed particle (as well as nuclear) mass spectrum, and the origin of the extreme weakness of gravity (together with gravi-strong force unification). This result, closely related to the dynamic unification of fundamental forces in our
theory, has strong consequences for various applications of Planck units and the entire high-energy physics and accelerator strategy [1,2,6,8-12]. While many key constructions in usual cosmology, quantum gravity and field theory become inapplicable to the real world, the dominating high-energy physics direction of blind search for ever heavier particle species becomes explicitly meaningless and should be replaced by the detailed studies of complex interaction effects within the already achieved energy scales.

Further extension of causally unified particle properties involves unreduced complexity features on the e/m protofield side, based on the standard relation between the elementary charge and Planck’s constant, $e^2 = \alpha \hbar$, already causally extended above, if we rewrite it as

$$E_e = m_e c^2 = \frac{2\pi}{\alpha} \frac{e^2}{\lambda_C} = N_{\Re}^e \frac{e^2}{\lambda_C}, \quad \lambda_C = \frac{\hbar}{m_e c}, \quad N_{\Re}^e = \frac{1}{\alpha}, \quad \lambda_C = \frac{\lambda_C}{2\pi},$$

(41)

where $m_e$ is the electron rest mass and $\lambda_C$ the Compton wavelength (see eq. (31)). It becomes evident from eq. (41) that $N_{\Re}^e = 1/\alpha$ ($\approx 137$) is the realisation number of the electron as the dynamically multivalued quantum beat process and $\lambda_C = \lambda_C / 2\pi$ ($\approx 3.9 \times 10^{-11}$ cm) the length of the electron quantum leap between its localised realisations (both defined up to a numerical coefficient of the order of $\pi$), in accord with the above interpretation of eqs. (30), (31) [1,2,5,8-12]. The fine-structure constant $\alpha = 1/N_{\Re}^e$ coincides thus with the electron realisation probability, $\alpha = \alpha_r$, where $\alpha_r$ is our universal dynamic probability of eq. (12a).

This causal complex-dynamic origin of fundamental constants is further specified by yet another form of the same $e-h$ relation:

$$\hbar = N_{\Re}^e \frac{e^2}{c} = \lambda_C p_e, \quad \lambda_C = N_{\Re}^e r_e,$$

(42)

where $p_e = m_e c = E_e/c$ and $r_e = e^2/m_e c^2$ ($\approx 2.8 \times 10^{-13}$ см) is the standard "classical electron radius". As mentioned above (see the end of the first section), each elementary particle kind can be considered as a global, compound (many-particle) realisation of the effective potential of protofield interaction. Therefore the first relation of eq. (42) can be interpreted as the expression for the particle’s EP well “volume” given by $\hbar$, while $N_{\Re}^e$ or $\lambda_C$ express its width and $e^2/c$ or $p_e$ its depth. The ultimate causal origin of the Planck constant and its absolute universality (for various quantum systems) emerges now as the fixed EP well volume, while its width and depth vary for different
species. The EP well volume is fixed due to the mechanical balance between shallow but wide and deep but narrow protofield deformations with the same EP volume, naturally expressed in units of action-complexity. Global realisations of light, leptonic particles, such as the electron, correspond to wide and shallow EP with $N_{\text{el}} \gg 1$ and $\alpha_r, \alpha \ll 1$ (for respective interaction constants), while the heaviest hadronic species produce deep and narrow EP wells with $N_{\text{h}}$,$\alpha_r \sim 1$. The entire diversity of dense enough, “quantum” particle species and agglomerates (e.g. nuclei) falls in between those limiting cases, thus supporting the unified dynamic origin of emerging particle species, fundamental constants and interaction forces in our theory.

The second expression of eq. (42) implies also that the size of each regular, corpuscular realisation of the electron (i.e. the virtual soliton of its quantum beat) is $r_e$, since the EP width $\Delta C$ contains exactly $N_{\text{el}}^e$ elements of that size, filling densely the available EP width. This conclusion corresponds to the conventional origin of the classical electron radius, as well as to the general rule that the regular realisation size expresses the size of real space “point” of a given complexity level, $r_0 = \Delta x_i = \Delta_0 \eta_i^e$ (see the beginning of this section), so that for this, lowest complexity level $r_0 = r_e$ (up to a moderate numerical coefficient of the order of $\pi$), which emerges as a new, natural but deeper interpretation of the classical electron radius.

In summary, we obtain thus the unified complex-dynamical, interaction-based origin of all observed fundamental structures, properties and constants $c$, $h$, $\alpha$, $e$, and $\gamma$ (including causal explanation of their universality), while usual theory simply postulates these properties and constants as separated, empirically based but basically abstract features. This key difference is important, in particular, for natural solution of cosmological fine-tuning problem (see the next section). The same advantage leads to the well-defined dynamic origin and finite spectrum of elementary particles and their masses, without any inexplicable “gap” (the “hierarchy problem”) or additional, abstract and contradictory entities of unitary theory (such as the Higgs field or “hidden” dimensions), where the highest observed mass-energy features (such as the presumed “Higgs boson mass” of standard theory) simply correspond to the unified “breaking point” of the coupled protofields, their highest interaction amplitude, and “electro-weak energy scale” (the e/m protofield strength in our interpretation) [11,12].
Complex-dynamic cosmology and the emerging global features of the Universe without missing entities

As demonstrated in the previous section, our unreduced, dynamically multivalued interaction analysis provides a “naturally cosmological”, emergent picture of the world structure. However, some “global”, Universe-wide and properly cosmological features of thus obtained complex-dynamic reality need special attention, also because they are essentially different from the usual theory framework and contain natural solutions to persisting and growing “difficult” problems of standard cosmology [9-11].

We have seen, in particular, that global, physically real space with exactly three dimensions (dynamic degrees of freedom) and permanently irreversibly flowing time naturally emerge as the dynamically multivalued, always changing entanglement of interacting e/m and gravitational proto-fields. The unidirectional time flow has additional cosmological implication: according to the universal definition of energy-complexity, eq. (19), positive time increment, $\Delta t > 0$, with always decreasing action-complexity, $\Delta A < 0$ (due to the dynamically random realisation change [1,2,28]), gives strictly positive total energy, $E > 0$, including that of the entire Universe. This conclusion is at variance with standard theory, which insists on the zero value of the total Universe energy (thus permitting its emergence “from nothing”), which then splits into positive mass-energy and negative energy of gravitational attraction compensating each other exactly. This difference has various important consequences and a deep physical meaning as the total energy positivity in our description originates in chaotic change of multiple system realisations, which are artificially reduced to only one, unchanged (timeless), realisation in conventional unitary “models” (thus pushing the rest of real, multivalued system dynamics to “hidden” and “dark” matters).

The Universe energy-complexity positivity and the related direction of physically real time flow can be expressed in other words as intrinsic dynamic creativity of any real, complex-dynamical, interaction-driven universe (in opposition to absent real time, null total energy of the Universe and its non-
emergent, only artificially inserted structure in usual, unitary cosmology). This important property can be rigorously and universally expressed by the universal symmetry, or conservation and transformation, of complexity [1,2,9-11,14-24,28]. It is based on the fact that the system realisation number \( N_\text{r} \) and thus the total system complexity \( C(N_\text{r}) \) (see eq. (14)) is determined by the number of interacting degrees of freedom or their combinations (see eq. (11)) fixed by the initial system configuration and remaining therefore unchanged during further structure development process.

The total dynamic complexity \( C \) of any (isolated) system or interaction process, including the Universe, is thus absolutely and universally conserved, \( \Delta C = 0 \). However, something should change in such global system characteristic as complexity during its structure formation and evolution, and it is the form of dynamic complexity, changing from the potential form of always decreasing dynamic information, \( I \), to permanently increasing dynamic entropy, \( S \), expressing the dynamic complexity of already appeared structures, so that their sum, the total dynamic complexity \( C = I + S \), remains unchanged: \( \Delta S = -\Delta I > 0 \). Complexity conservation is thus realised only by its unstoppable, interaction-driven transformation from the latent form of dynamic information to the explicit form of dynamic entropy, which is equivalent to the universal symmetry (of complexity) of emerging structures, their dynamics and evolution (whereas in unitary theory its postulated, abstract and often “spontaneously broken” conservation laws are related to but different from respective symmetries). And since action-complexity \( A \) introduced above (see eq. (17)) is a unified decreasing measure of complexity, it is naturally identified as the universal expression of dynamic information, \( A = I \), so that the universal symmetry of complexity, describing the creative evolution of any real system, including the Universe, is expressed mathematically as

\[
\Delta S = -\Delta A > 0 .
\]

A major implication of this unified “creativity law” for the observed Universe properties appears as the naturally self-tuning character of its structures, parameters and evolution, resolving the corresponding stagnating “mystery” of standard unitary cosmology. Since the latter does not consider universe structure emergence as a result of unreduced interaction process, postulating instead its over-simplified mechanistic models, it always remains with a mystery of “strange” coincidence between various parameter
values, without which no sensible world structure could ever exist. Our causally complete picture of unreduced protofield interaction does not contain this contradiction already due to its intrinsically interactive, emergent character, where any given, generic interaction magnitude dynamically produces respective structures, interactions and parameters, whose “happy coincidence” is ensured by their dynamic origin described above. It is illustrated by the clearly specified dynamic origin of fundamental constants \( c, h, \alpha, e, \gamma \) and their relations (see the previous section, eqs. (40)-(42)).

If we consider the origin of the material content of the Universe, then we see that according to the complexity symmetry, eq. (43), the initial complexity stock in the potential form of global dynamic information of protofield interaction will progressively produce the corresponding quantity of dynamic entropy-complexity of real world structures, organised in the fractal hierarchy of complexity levels. Expressed in the differential form of, respectively, initial potential interaction energy in the system of coupled protofields, \( V_{\text{init}} = -\Delta A/\Delta t \), and mass-energy-complexity of emerging universe structures, \( M_{\text{univ}} c^2 = \Delta S/\Delta t \), this symmetry of creative evolution means that

\[
V_{\text{init}} = M_{\text{univ}} c^2 ,
\]

(44a)

where the internal adaptable splitting into suitable levels of complex-dynamical structures and interactions is assumed by the unreduced interaction development, in the form of dynamically multivalued fractal entanglement of interacting components (see the first section):

\[
M_{\text{univ}} = \sum_{s,l} \left( N_{sl} m_{sl} + \frac{V_{sl}}{c^2} \right) = \\
= \sum_{\text{part}} N_{\text{part}} m_{\text{part}} + \frac{V_{\text{fund}}}{c^2} \to \sum_{\text{atom}} N_{\text{atom}} m_{\text{atom}} + \frac{V_{\text{chem}}}{c^2} \to \ldots ,
\]

(44b)

with \( N_{sl} \) structures (numbered by \( s \)) with masses \( m_{sl} \) and interactions \( V_{sl} \) dynamically emerging at the \( l \)-th complexity level, starting from elementary particles (\( N_{\text{part}}, m_{\text{part}} \)) and their fundamental interactions \( V_{\text{fund}} \) as described in the previous section,\(^8\) followed by atoms (\( N_{\text{atom}}, m_{\text{atom}} \)) and their chemical

\(^8\) Note that the emergence of exactly one light (the electron) and one heavy (proton) stable elementary particle in our initial configuration of coupled e/m and gravitational protofields, with the natural relation of each of those particles to its “native” protofield (see the previous section), can also be explained by complexity conservation or the number of global realisations in the protofield interaction transformation into particle species at the first complexity level.
interactions $V_{\text{chem}}$, then forming molecules and further higher-complexity structures and interactions.

This dynamic fine-tuning property of the interaction-driven complex-dynamical universe will thus automatically produce a reasonably structured universe for various reasonable, generic parameters of initial protofield interaction. Only exceptional, too low or too high, interaction magnitudes would produce trivial, small and chaotic or permanently collapsed and dense, universe structures.

The possibility of suitable, “generic” protofield interaction parameters is additionally supported by the probable dynamic origin of the coupled protofield system from the initial “equilibrium” state of totally “collapsed” protofields, forming a single primordial quark-gluon condensate in its ground state (see also footnote 6 in the previous section). Indeed, if we assume that a certain, large enough volume of such primordial, effectively structureless ground-state of a quark-gluon condensate is excited by separation of its light and elastic gluon component(s) from the remaining heavy and rigid quark “matrix”, then we obtain a suitable version of our coupled protofield system, with the necessary “reasonable” parameters of the e/m protofield (gluon-based changeable and directly perceived “surface”), the gravitational protofield (the remaining dense quark-gluon matrix) and their natural coupling (due to the matrix depletion of gluonic fields) of a suitable “medium” magnitude. Thus originating protofield system with suitable structure-forming coupling will then naturally develop the properly fine-tuned consecutive levels of complexity, starting from physically real space, time, elementary particles with their intrinsic properties and fundamental interactions, as described above. While the origin of initial condensate excitation from its ground-state remains fundamentally unknown (in particular, it could result from a big enough fluctuation within a yet much larger quark-gluon condensate volume), it is evident that this or another way of introduction of the initial system action-complexity (dynamic information) stock is absolutely necessary, according to the undeniable complexity conservation law, which unifies causally extended versions of all known correct laws and principles, with their supporting observations [1,2,9-11,14-24,28] (whereas zero-energy-complexity universe models of usual unitary cosmology demonstrate heavy fundamental deficiencies, including absent time and only formally postulated abstract structures).
Thus emerging complex-dynamical, interaction-driven universe with positive energy-complexity has essentially different kind of global dynamics with respect to the unitary zero-energy model of conventional cosmology. The high positive value of real-universe complexity is actually due to its hierarchy of multiple realisations permanently changing in chaotic order, with the resulting highly irregular kind of dynamics and evolution, appearing as “dissipative”, “nonlinear” and “turbulent” at larger macroscopic scales, in contrast to mechanically ordered, over-simplified and “one-component” (single-valued) dynamics of standard unitary models. The latter underlie, in particular, the main Big Bang idea of global Universe dynamics in the standard unitary cosmology, considered as a simple, regular mechanical motion within a single homogeneous body of weak-interaction, e.g. gas-like, internal behaviour, which must either expand or contract under the influence of global gravitational and thermodynamic/mechanical forces.

The real, complex-dynamical system of basically the same observed material content, driven by the unreduced interaction of its components, will demonstrate a qualitatively different kind of behaviour dominated by dissipative, self-organised and chaotic processes of all scales that account for the main part of high positive energy of the Universe and do not imply any global simplified motion like uniform expansion or contraction. Hence the key Big-Bang idea of standard cosmology (actually experiencing huge difficulties and growing contradictions [56,57]) becomes fundamentally irrelevant for real Universe dynamics and evolution, including all related unitary mathematical models from classical and quantum cosmology (e.g. inflation theory with implications), astrophysics, field theory and particle physics, which cannot be valid, even approximately, as a reasonably complete description of reality, while preserving their formal “validity”, similar to the Ptolemaic system. By contrast, the unreduced, multivalued and multilevel protofield interaction development provides various “nonlinear” features to cosmic structure dynamics, explaining the otherwise ever more “mysterious” and scandalously dominating contributions of “dark matter” and “dark energy” to the observed Universe dynamics [9-11] (see below).

One can say, in other words, that the real Universe driven by the unreduced, multilevel interaction process is an intrinsically creative, structure-forming and in that sense “living” system, as opposed to its global vision of a simple, mechanically expanding or contracting “body” in the standard
cosmology. This dominating structure creation capacity of the real world, replacing its mechanical Big Bang expansion of the unitary model, is largely due to the exponentially huge efficiency of the dynamically probabilistic fractal of the unreduced interaction result, explaining also the "magic" properties of life, intelligence and consciousness [2,11,14-24,28]. Extremely large numbers of permanently breeding and interactively changing realisations of the dynamically multivalued fractal structure correspond to the underlying symmetry of complexity of the protofield interaction process maintained by permanent transformation of potential information-complexity to the dynamic entropy-complexity of emerging universe structures. The key point of the dynamic redundance paradigm, resolving various problems of standard cosmology, is that any, however externally ordered structure creation process corresponds to the dynamic entropy growth, rather than fall in unitary theory, due to the growing numbers of randomly changing incompatible realisations, even within any externally regular shape (explaining also the omnipresent intrinsic time flow within any process or object) [1,2,9-11,28].

We thus obtain the permanently essentially changing, intrinsically creative Universe without global mechanical expansion (replaced by complex-dynamical structure formation on any scale), which therefore does not contain any persisting problems of the standard Big Bang cosmology, such as the observed Universe flatness or the horizon problem (hence we don’t need any contradictory “inflation”), as well as various problems with the mechanistic “age of the Universe” badly interfering with the Big Bang and particular structure dynamics. In addition to the natural dynamic “fine tuning” of the emerging universe structures described above, we have the rigorously derived causal origin and explanation for the universality of fundamental constants, particle properties and time flow throughout the Universe, due to the underlying (synchronised) quantum beat dynamics in the system of coupled protofields (see the previous section). These properties are just taken for granted in usual cosmology, but they actually need and do have a well-specified and deeply rooted dynamic origin.

One should separately mention two major features as if “definitely confirming” the Big Bang assumption, the microwave background radiation and the redshift of light arriving from distant sources. In fact, our complex-dynamic cosmology provides different, much better substantiated explanations
for these features and avoids serious contradictions in their conventional Big-Bang interpretation.

The background radiation emerges in our description as the inevitable consequence of the coupled protofield system perturbation by the quantum beat processes of massive elementary field-particles and the hierarchy of their interactions leading to the quasi-equilibrium “thermal” photon distribution at a given (advanced) stage of Universe complexity development. Because of the fine-tuned saturation of the developed universe structure with massive particles described above, their further interactions and energy-exchange processes can produce only massless photonic excitations in the coupled protofield system (and maybe neutrino excitations, which do not change the conclusion). While higher energy photons participate in various local, nonequilibrium interactions, the low-energy, “background” part of photonic radiation congregates into a thermalised radiation peak, without any relation to the Big Bang history of the Universe assumed in conventional cosmology. Such “thermodynamic” origin of the microwave background radiation is actually obtained within any reasonable cosmology without expansion [58], while our unreduced description of complex protofield interaction dynamics provides additional refinement of the sources of photonic excitations and their fine-tuned adjustment to the complex interaction dynamics of the coupled protofield system of the Universe.

The redshift interpretation in our approach, equally avoiding any Big Bang expansion hypothesis, bears a much deeper relation to the detailed complex dynamics of the coupled protofield system and related physical origin of photons. We note, first of all, that the conventional implicitly postulated assumption about the absolutely nondissipative nature of photons contains a very general and fundamental contradiction to the principle of energy degradation (the second law of thermodynamics) that can be formulated in a general form just as impossibility of such real nondissipative structures in the interactive universe environment (as further specified by our universal symmetry of complexity, see above in this section, eq. (43)). This contradiction appears, in particular, in the conventional redshift interpretation as being due to nondissipative photon frequency change (decrease) as a result of a Doppler kind of purely mechanical effect (irrespective of its detailed explanation by “space extension” etc.). If now we do accept the necessary dissipativity of real photons, then we can immediately see its origin in the moving
photon interaction with the underlying gravitational protofield material represented most probably by a dense quark-gluon condensate (see above). The small magnitude of this interaction and related photon dissipativity is due to the relatively small effective protofield coupling for these weak e/m protofield perturbations.

This cosmologically important feature of photon energy dissipation is closely related to the causal, physically real photon nature remaining unspecified in standard theory. In our unified complex dynamics of the Universe, photons naturally emerge as relatively weak excitations of the e/m protofield coupled to the gravitational protofield, which cannot develop into much stronger, highly nonlinear deformations of quantum beat processes for massive elementary particles because of the essentially higher e/m protofield tension saturated by the already existing massive particles. It explains the validity of basically linear description of e/m waves/photons, as well as of a somewhat similar state of the intermediate realisation of the wavefunction for massive particles introduced in the first section (Schrödinger equation, see [1,2,9-11]). However, as the protofield coupling never vanishes, even this weak, externally linear photonic excitation of the e/m protofield should possess its dynamically nonlinear core and behaviour. Indeed, although the e/m protofield Hamiltonian $h_e(q)$ in the system existence equation (1) could describe small quasi-linear oscillations, its interaction with the omnipresent gravitational protofield, $h_g(\xi) + V_{eg}(\xi,q)$, leads necessarily to the dynamic nonlinearity in the form of effective self-interaction, according to the unified EP mechanism, eqs. (8)-(9) (where $\xi$ can stand for the emerging space coordinate or respective degrees of freedom of the e/m protofield).

The obtained small but internally nonlinear e/m protofield excitations can be modelled e.g. by a nonlinear Schrödinger equation with dissipation, being one of the reduced versions of our general EP equation (8)-(9). This kind of equation possesses soliton solutions, which will show dissipation for the case of dissipative terms due to irreducible coupling to the gravitational protofield degrees of freedom (represented most probably by a quark-gluon condensate with strong internal interactions). The protofield coupling provides therefore the double effect of dynamic shape-preserving nonlinearity of these e/m protofield solitons (due to attraction to the underlying gravitational protofield) and their weak dissipativity, appearing as slow energy degradation in long-distance propagation. These are just the desired properties.
of the observed e/m quanta, or photons, explaining the origin of both their localised, corpuscular behaviour (different from quantum-beat behaviour for massive particles) and the cosmological redshift as inevitable and now unified features provided always by the same driving protofield interaction, without any additional assumptions or entities (like the Big Bang or various higher-level photon interactions). The linear wave behaviour of these internally nonlinear photons is provided by extended oscillations surrounding the nonlinear soliton core. These conclusions are partially confirmed by recent soliton model of the photon [59], even though the underlying protofield interaction and related weak redshift dissipation are not considered in this purely electromagnetic model.

Further important observed feature of the cosmological redshift, naturally explained within this dissipative soliton dynamics of photons (and remaining ever more mysterious within usual theory) is the “accelerated Universe expansion” phenomenon appearing as nonlinear redshift growth with distance and giving rise to the major unsolved problem of “dark energy” (see e.g. [60,61]). In our picture it becomes evident that photon energy dissipation can and even should depend on propagation distance in a generally nonlinear way, without any necessity for new entities that should give rise to the dark-energy repulsion and accelerated expansion in the standard mechanistic universe model. Moreover, the same complex-dynamical redshift origin should give rise to numerous observed anomalous redshift features for particular distant objects (being otherwise another mystery of usual cosmology, cf. [56,57]) due to the respective object mass-energy and gravitational protofield density influence. While further detailed studies (e.g. of interaction-based dissipative soliton dynamics for photon redshift effects) compared to various observations can provide a more comprehensive description of our complex-dynamic Universe parameters, there is little doubt that already the combination of major features mentioned here, including the inevitable photon dissipativity, cannot be consistently described in any essentially simplified way, such as the conventional Big Bang or any other mechanistic, dynamically single-valued universe model.

One should mention here another related and persisting mystery of conventional cosmology, the cosmological constant (or vacuum energy) problem. Quantum vacuum energy, presumably giving rise to the positive cosmological constant that contributes to the mechanical Big Bang expansion of
standard cosmology, originates in “quantum fluctuations” of the vacuum in the form of virtually appearing particles as a result “quantum energy-time uncertainty principle”. Energy density calculations for such virtual particle processes within usual theory give values exceeding the observed maximum (small) values of the cosmological constant by many orders of magnitude. Contrary to these formal calculations, our complex-dynamical mass-energy origin in the form of clearly specified quantum beat processes in the dynamically unified protofield system, together with the universal complexity conservation law, implies that no massive particle can actually emerge from “nothing” in vacuum, even “virtually” (for a short time), except massless photons (and maybe other quasi-massless species), which do not provide noticeable vacuum energy and cosmological constant values and practically appear rather as microwave background radiation specified above (in other frequency ranges, they also account for the observed Casimir effect and Lamb shift in atomic energy spectra). In relation to the self-tuned particle emergence in our dynamically adaptable universe described above, it means simply that local mechanical properties of the “vacuum” of coupled protofields can permit only small photonic, massless perturbations to appear in a basically developed, massive-particle-saturated and thus mechanically “strained” universe, which in any case will produce or swallow its structures, rather than mechanically expand or contract as a whole.

In summary, either excessive vacuum energy and huge cosmological constant or repulsive dark energy of unknown origin simply do not appear in our description (as well as the related “mysteries” of usual cosmology), due to the causally complete, self-adaptable construction of the Universe, with only explicitly, dynamically emerging entities and laws naturally corresponding to observations.

Another series of standard-cosmology problems of the same “missing-complexity” origin appear as dark matter effects [61-67]. While the above dark energy illusion is due to microscopic protofield interaction effects not taken into account in standard mechanistic Universe models, the apparent dynamic influences of invisible, or “dark”, mass are due to equally neglected dynamically multivalued motions within a wide range of complexity levels, from protofields to big astrophysical objects and structures [2,9,10]. For a concrete but actually general enough demonstration of those “dark matter” effects of macroscopically missing dynamic complexity, one can start with
the standard virial theorem (see e.g. [68]) often applied to galaxy velocity (and thus mass) distribution estimates:

\[ 2\bar{T} = -\bar{U}, \]  

(45)

where \( \bar{T} \) and \( \bar{U} \) are time-averaged values of kinetic and potential energy for a system of gravitationally interacting bodies. However, in real, multivalued system dynamics this regular, dynamically single-valued kinetic energy from the usual virial theorem, \( \bar{T} = \bar{T}_{\text{reg}} \), is only a small part of the real, chaotic kinetic energy \( \bar{T}_{\text{real}} \):

\[ \bar{T}_{\text{real}} = \bar{T}_{\text{reg}} N_{\text{sr}}, \]  

(46)

where \( N_{\text{sr}} \gg 1 \) is a certain “effective” number of realisations for the considered system and observation kind.

While the observed object potential energy \( \bar{U}_{\text{obs}} \) corresponds to the real kinetic energy, \( 2\bar{T}_{\text{real}} = -\bar{U}_{\text{obs}} \), the unitary, deficient version of system dynamics (45) states that \( 2\bar{T}_{\text{reg}} = -\bar{U}_{\text{obs}} \), leading to the false discrepancy, \( \delta \)

\[ \delta = \frac{\bar{T}_{\text{real}}}{\bar{T}_{\text{reg}}} = N_{\text{sr}}, \]  

(47)

in accord with eq. (46). Within the unitary model it can only be explained as being due to the “invisible”, or “dark”, but actually present matter mass, \( M_{\text{dark}} = M_{\text{real}} - M_{\text{reg}} \), so that

\[ \frac{M_{\text{real}}}{M_{\text{reg}}} = \frac{\bar{T}_{\text{real}}}{\bar{T}_{\text{reg}}} = \delta = N_{\text{sr}} \quad \text{or} \quad M_{\text{dark}} = M_{\text{reg}} \left( N_{\text{sr}} - 1 \right) \approx M_{\text{reg}} N_{\text{sr}}. \]  

(48)

In reality it means that instead of additional mass there is excessive, chaotic motion, or (deviating) velocity \( v \), in the unreduced system dynamics as compared to reduced unitary expectations: as \( \bar{T} \propto \sqrt{M v^2} \), eq. (47) gives

\[ \left( \frac{v^2}{\bar{v}^2} \right)_{\text{real}} = N_{\text{sr}} \left( \frac{v^2}{\bar{v}^2} \right)_{\text{reg}}. \]  

(49)

This result is generalised for the distance-dependent case of “rotational curves” for galaxies (or other structures), where the “anomalous” dependence of (average) rotational velocity on the distance from the centre of mass, \( v(r) \), is not due to anomalous mass distribution \( M(r) \) (attributed to “dark matter halos”) but due to “unexpected” (in the unitary model), complex-dynamical contributions to \( v(r) \), which are proportional not to \( \sqrt{M_{\text{reg}}(r) + M_{\text{dark}}(r)} \) but to \( \sqrt{N_{\text{sr}}(r)} \) (see eqs. (48), (49)), so that

\[ v(r) = \sqrt{\frac{\gamma N_{\text{sr}}(r) M_{\text{obs}}(r)}{r}} \quad \text{or} \quad N_{\text{sr}}(r) = \frac{r v^2(r)}{\gamma M_{\text{obs}}(r)}, \]  

(50)
where \( M_{\text{obs}}(r) = M_{\text{real}}(r) \) is the ordinary, “visible” mass within radius \( r \), and one can derive the features of chaotic system dynamics, \( N_{\text{r}}(r) \), from the observed dependencies \( v(r) \) and \( M_{\text{obs}}(r) \). In particular, the observed growth of thus defined \( N_{\text{r}}(r) \) just in “looser”, more chaotic system parts, as well as its large variation for different kinds of cosmic structures, correspond well to fundamental laws of unreduced chaotic dynamics \([2,9,10]\).

As a result, one can advance a general qualitative rule for the behaviour of real, complex-dynamical systems of many bodies mutually attracted according to the inverse-square law (any nondissipative attraction in three-dimensional space), in particular, many-body astrophysical structures. Due to the interplay between the “ordering” attraction to the global and local centres of mass (or another relevant “charge”) and disordering influence of multivalued chaotic trajectories, such generic systems would tend to a somewhat smeared splitting into more regular system cores around centres of mass and much more chaotic “outskirts” farther from big attraction centres accumulating various chaotic “debris” expelled from the “self-organised” core regions and following “nonclassical”, explicitly multivalued dynamic behaviour laws, which appear, in particular, as the observed “dark matter” effects.

The detailed mechanism of such “chaotic halos” creation would include the multivalued chaos-driven sub-barrier tunnelling \([1]\) from the potential well of the well-known classical “effective potential” of motion in the central inverse-square field \([68]\):

\[
V_{\text{eff}}(r) = -\frac{\gamma mM}{r} + \frac{L^2}{2mr^2},
\]

where in our case \( M \) is the (big) central mass, \( m \) is the (smaller) mass of a moving body, \( L \) is the (conserved) angular momentum of the moving body, the first term is the direct (here gravitational) attraction, and the second term is the “centrifugal force” contribution. This effective potential function has the form of a smooth asymmetric potential well with the depth \( \Delta V_{\text{eff}} = \gamma^2 M^2 m^3 / 2L^2 \) \([68], \S\ 15\). While in this simplest one-body formulation \( \Delta V_{\text{eff}} \) remains fixed, the multivalued fluctuations in the real many-body system dynamics will produce random increases of \( L \), lowering the barrier and initiating the (quite classical) subbarrier tunnelling effect (see also section 2.4 in ref \([2]\) for the general causal theory of subbarrier tunnelling).

In other words (see also section 8.2 in ref. \([2]\)), because of smaller interaction of outgoing system components with the inner system mass, the
The net result of the emerging dynamical chaos will be the permanent, progressive diffusion of higher-speed “off-track” chaotic components from inner, higher-speed trajectories to outer trajectories and eventually vast regions (including the system’s “free space”, e.g. beyond the galactic disk plane for spiral galaxies). In one way or another, due to the intrinsic and often strong chaoticity, large quantities of “anomalous” high-speed components accumulate just in those “chaotic outskirts” regions of many-body gravitational systems, where they behave in a highly random way, contributing to the increased $N_{3R}(r)$ from eq. (50) in these system parts.

It is important to note that complex-dynamical contributions to the observed velocity, or motion, in more chaotic system parts with higher $N_{3R}(r) \gg 1$ can come from various components of multivalued system dynamics, including not only multivalued chaotic trajectories and larger quantities of smaller, directly unobservable “junk” elements intensely pushed to such chaotic outskirts but also more subtle effects of underlying inhomogeneous gravitational protofield density induced by the directly observed e/m protofield dynamics. Indeed, while the gravitational protofield density grows within massive objects due to their quantum beat processes, it should be respectively depleted just around their denser central parts and again increase at larger distances, which may have the effect of additional “invisible mass”. In other words, the dark matter effects may partially result from complex dynamics of the underlying (and directly indeed unobservable) gravitational protofield itself represented most probably by a strong-interaction quark-gluon matter. It is the relative importance of these various possible contributions to chaotic dynamics of astrophysical objects that should constitute a major direction of further experimental and theoretical research in astronomy and cosmology, as opposed to the dominating applications of deeply incorrect unitary models (including the popular MOND hypothesis [61,62,66,67]). In a general sense, those different “dark matter realisations” of multivalued cosmic structure dynamics correspond to the intrinsically creative Universe dynamics driven by its unreduced interactions and just missing par excellence in heavily reduced unitary models of conventional cosmology, hence unable to solve this yet another “puzzle” within its artificial limitations.

In summary of our causally complete complex-dynamical (multivalued) cosmology as compared to mystified and puzzling unitary cosmological models, we return to the lowest complexity level of our unified,
physically real elementary particles and fields (see the previous section) to conclude that the natural richness of multivalued interaction dynamics permits us to avoid a plethora of artificial, abstract, separated and strangely “invisible” entities (fields, particles and dimensions) that still do not solve the growing unitary-science problems, in favour of naturally emerging, intrinsically unified and sufficient properties, features and structures of unreduced, multivalued dynamics of the underlying multilevel but unified protofield interaction process. That causal completion of the fundamentally deficient unitary model can be conveniently generalised by saying, in accord with the unified relations (19), (26)-(28), that we provide, in our complex-dynamical description, various levels and aspects of the otherwise heavily missing total mass-energy-complexity of the Universe structure, from our universal inertial and gravitational mass definition to naturally absent “dark” matter and energy and strictly positive (and high) total energy-complexity of the Universe.

A major kind of fundamentally redundant entities of unitary theory, invented to replace real but “hidden” features (or “variables”) of complex interaction dynamics, is represented by additional, in particular scalar, fields and particles, including the Higgs field and bosons. While their existence is at variance with the observed, minimum number of dimensions and interaction forces (see the previous section), an additional consideration implies that scalar fields are rather improbable as such [12] because their interaction with other fields would provide their quanta with nonzero spin, similar to spin emergence in interaction between the e/m and gravitational protofields, unless they simulate the gravitational protofield itself. This conclusion invalidates so many abstract constructions of unitary cosmology and field/particle theory just relying on the assumed existence of additional, often scalar fields.

Another redundant feature of standard cosmology is the fundamental Big Bang expansion itself (and its related previous or next possible contraction). While we explained above why this mechanistic feature is absent in real complex-dynamical Universe (being replaced by multilevel and highly nonlinear structure creation processes with growing entropy-complexity), one may also think about the “edge of the Universe” and its dynamics in this real world, driven by the unreduced protofield interaction. In our case it depends on the assumed origin of the coupled protofield system. If we apply the Ockham’s principle of parsimony to this “pre-cosmological” process (see previous sections), we should conclude that the e/m protofield coupled to
the gravitational protofield emerges as a result of initial excitation of a large enough portion of basically gluonic components from the primordial ground-state quark-gluon condensate thus transformed to the gravitational proto-field. While the edge of this initial global excitation can move in an arbitrary (unknown) way, the observed Universe structure is determined by the proto-field interaction results and can advance, in particular, by propagation of the global quantum-beat synchronisation process that gives rise to the universal real time flow and electric charge with its exactly two “opposite” kinds (see the previous section).

While this real Universe edge dynamics has nothing to do with the global Big Bang expansion (or any other mechanistic universe dynamics) replaced by local complex-dynamical structure creation, it can produce large-scale inhomogeneities of Universe properties, which could contribute to the origin of “nonlinear redshift” or (seeming) “dark energy” problem at larger distances and for some distant and peculiar super-high-energy objects and events. In other words, those extreme domains and objects could contain more unstable, still forming fundamental structures of space, time and field-particles, as described in our emergent universe picture, in this and the previous section. Such special cases can provide a unified diversity of origins of various observed “deviations” and “inexplicable” effects in redshift and energetic radiation distribution and production.

Another related group of accumulating “difficult” problems of usual cosmology is that of the age of the Universe, where its “well-established” Big-Bang value (of around 14 billion years) seems to be at variance with the age of some ultimately distant and thus “very young” but already well-formed detected objects (such as galaxies). These problems are related to the oversimplified model of mechanistic global dynamics of usual cosmology. Correspondingly, they do not even appear in the complex-dynamical, interaction-driven universe picture, where the age of the Universe is determined by extremely complicated detailed evolution of the huge hierarchy of unreduced dynamic complexity of universe structure. It could be provided with a more definite basis, if observations finally reveal the above moving “synchronisation” (and structure-formation) edge of the Universe (and the accessible large-distance data should be studied more attentively from that point of view). In any case the obtained age of real, complex-dynamical Universe will be much greater than the mechanistic Big-Bang age already because the
speed of complex-dynamic synchronisation and structure-formation propagation should be essentially smaller than the speed of light arriving from respective, already quite distant “event horizon”. This conclusion corresponds to the generally much longer, multi-stage and “entangled” process of complex-dynamical structure formation and evolution as compared to straightforward mechanical expansion or contraction. As a result, we obtain a quite different strategy and direction of observational cosmology research based on the search for and understanding of real, explicit universe structure formation, rather than any simplified mechanistic model of its evolution.

The ultimate edge of the Universe in our picture would be the border of the Universe volume along which the two coupled but separated protofields collapse onto one another to form the primordial ground state of the quark-gluon condensate outside the Universe. While this ultimate frontier of the Universe may well be beyond any observational limits and much farther than the real “synchronisation edge” of usual Universe structure described above, it probably has its local internal version in the form of now realistically explained black hole “singularities”. Indeed, the origin of these central singularities and black holes in general is naturally seen in our universe construction as small local remnants of the primordial “collapsed”, ground-state quark-gluon condensate prior to the protofield separation in the Universe volume. They actually serve as additional structure-regulating feature, where the protofields are locally “pinned” to each other, thus maintaining their necessary tension and matter-carrier properties in large spaces around and between relatively dense structures (usually galactic centres). It is quite probable that at least a part of (greater) black hole “singularities” thus explained exist since the Universe creation (e.g. by initial protofield separation) as real remnants of the primordial ground-state condensate, which would explain contradictions around younger black hole age. Other black holes could emerge by standard mechanisms of gravitational collapse, but now understood as eventual collapse of the protofields (within the central “singularity”) returning them to their primordial state of lowest energy, complexity and structure.

The physically real structure of these causally understood black hole cores can be seen as a spectrum of possible ultimately dense states of “condensed” field-particles (quantum beat processes), being denser analogues of neutron stars (they could be called correspondingly “quark-gluon stars” or
“Planck stars”). The highest density limit is provided by the closely packed species with the parameters of modified Planck units (see eqs. (39)-(40)), \[ \rho_p = M_p / (L_p)^3 = c^5 / (\gamma_0)^2 \hbar \sim 10^{27} - 10^{29} \text{ g/cm}^3 \] [1]. This is some 14 orders of magnitude higher than the nuclear star or nucleus density \( \rho_{\text{nucl}} \), and various intermediate densities \( \rho_{\text{nucl}} \ll \rho < \rho_p \) can also be realised. They will vary with the condensed species mass \( M \) approximately as \( M^4 (\rho = M^4 c^3 / \hbar^3) \), up to more involved structure of condensed phases. In all cases, the microscopic dynamic origin of major properties of a black hole is clarified: virtually no e/m protofield excitations (either photons or massive particles) can escape this highly condensed core of the collapsed protofields because of its “closed” dynamics, where almost all excitations are immediately absorbed in the same condensate (in some relation to the quark confinement interpretation in our theory, see the previous section).

Finally, we mention an interesting new fundamental feature of our complex-dynamical Universe structure related to its quantum beat synchronisation being at the origin of electric charge and physically real time continuity throughout the Universe (as shown in the previous section). It provides a new outlook on the old and stagnating problem of the wavefunction of the Universe, originating in conventional “quantum cosmology”. While it may seem that modern, predominantly “classical” state of the Universe is incompatible with the idea of a single wavefunction for the entire universe, the quantum beat synchronisation for all field-particles of the world, combined with our causal interpretation of the wavefunction (see the first section), points to the fact that the wavefunction of the Universe can still be considered as a real entity represented by the unified, simultaneously taken intermediate realisation of all quantum beat processes of the Universe. It can hardly be spatially coherent throughout the entire Universe and in this sense is closer to the classical distribution-function version of the wavefunction. However, the unique temporal coherence of this undular state of the e/m protofield in our picture permits us to see it as a deep enough version of the global wavefunction of the world, confirming its interaction-driven dynamic unity. The entire Universe in this global wavefunction realisation simultaneously “changes its face” towards the diversity of next regular, localised realisations by transiently returning to its structureless initial state, within the global quantum beat process of the Universe thus obtained.
In summary, we obtain variously dynamically unified and intrinsically creative, truly “cosmological” and “emergent” structure of complex-dynamical Universe, including not only the described fundamental but also all higher-complexity objects, in the form of dynamically probabilistic fractal [1,2,9-11,28]. The omnipresent fractal interaction web, in its unreduced, dynamically multivalued version, explains also the observed large-scale quantisation of planetary systems and greater structures [69,70], otherwise lacking a real physical substantiation (see ref. [2], section 8.2 for more details). And although many features of the presented complex-dynamic (multivalued) cosmology need further detailed study, the already obtained results and especially the unified and qualitatively totally consistent general dynamical structure of the Universe point to the necessity of the corresponding decisive complexity transition in cosmology, essentially extending its artificially limited unitary, mechanistic framework and naturally solving all the accumulated problems of the latter.
Causally complete structure emergence and dynamics at higher complexity levels: Unreduced nanobiotechnology, reliable genetics, integral medicine, demystified consciousness, and sustainable world development without crises

In previous sections we reviewed the causally complete universe structure emergence mainly at the few lowest sublevels of the fundamental unifying process of interaction between two primordial protofields, as well as its global, cosmological features for all complexity levels involved. Starting from the level of physically well-defined elementary field-particles (as described in the first two sections), the unified complex-dynamical interaction process, eqs. (1)-(3), proceeds to higher levels of interacting particles, including causally complete quantum measurement, genuine quantum chaos and dynamically emerging classical behaviour for elementary bound systems like atoms [1-11,13-15], and then further on to macroscopic bodies and structures while always preserving its causally complete dynamics without postulated mysteries, hidden variables, or dark matters of respective unitary science results [1,2,14-29]. All artificial limitations of the latter disappear due to our unreduced interaction analysis revealing the key extension to the fundamental dynamic multivaluedness of interaction results (see the first section).

It is those dynamically multivalued results of any real interaction process that constitute the unified "hidden" variables (or dimensions, or particles/energy, or "many worlds") of unitary science, desperately lost within its artificially simplified, dynamically single-valued framework. Rather than being mysteriously hidden from direct observation, these unreduced, dynamically multivalued versions of all real interaction processes permanently appear and disappear in dynamically random order, giving rise to universally defined chaoticity, complexity and naturally irreversible time flow.

Before briefly outlining below the results of this universal and causally complete interaction development process at higher complexity levels, we emphasize its unified guiding laws and features [1,2,10,28-30]. The main encompassing law is the universal symmetry of complexity introduced in the
previous section, which is the unified and causally derived extension of all (correct) particular laws and “principles” of real world dynamics, now also liberated from their formally postulated, abstract and mysterious origin in unitary theory. In its integral form, the unified complexity symmetry is expressed as the permanent transformation of the potential quantity of action-complexity (or dynamic information) $A$ to the equal amount of unfolded quantity of action-entropy (or dynamic entropy) $S$, eq. (43).

In cases of relatively smooth (fine-grain) dynamics within a given complexity level, the differential form of the same complexity symmetry can be more useful. It is obtained by division of eq. (43) by the dynamically discrete time element, $\Delta t|_{x=\text{const}}$, leading to the discrete (in general) version of the generalised Hamilton-Jacobi equation:

$$
\frac{\Delta A}{\Delta t}|_{x=\text{const}} + H\left(x, \frac{\Delta A}{\Delta x}|_{t=\text{const}, t}\right) = 0, \quad H = E > 0,
$$

which is accompanied by the universal Schrödinger equation for the generalised wavefunction (or distribution function) $\Psi$ introduced in previous sections and describing the intermediate, or main, realisation state $[1, 2, 7, 10, 11, 18-24, 28, 29]$:

$$
\mathcal{A}_0 \frac{\Delta \Psi}{\Delta t}|_{x=\text{const}} = \hat{H}\left(x, \frac{\Delta}{\Delta x}|_{t=\text{const}, t}\right)\Psi(x, t),
$$

where the generalised Hamiltonian, $H = H(x, p, t)$, is rigorously defined as a differential version of the unfolded, entropic complexity, $H = (\Delta S/\Delta t)|_{x=\text{const}}$ (justifying the initial interaction problem formulation (1)-(3)), in accord with the above definition of its eigenvalue of generalised (total) energy $E$, eq. (19), and the generalised momentum definition, eq. (18), while the momentum operator $\hat{p} = \mathcal{A}_0 (\Delta/\Delta x)|_{t=\text{const}}$ in eq. (52) replaces the momentum variable $p = (\Delta A/\Delta x)|_{x=\text{const}}$ and the causal Born rule, eq. (13), relating the generalised wavefunction values with the realisation probability distribution is added to the generalised Schrödinger formalism (52). Universal equations (51), (52) (together with the Born rule (13)) constitute the unified and causally complete Hamilton-Schrödinger formalism for any system dynamics, which generalises various particular dynamic equations and takes a simpler, time-independent form for isolated systems:

$$
H\left(x, \frac{\Delta A}{\Delta x}\right) = E \ (>0),
$$

where
The obtained differential expression of the universal complexity symmetry, eq. (51), contains also the dynamically derived arrow of time, directed to entropy-complexity growth (or action-complexity decrease), $H, E > 0$, which is the generalised, differential version of the energy degradation principle (entropy growth, or the “second law of thermodynamics”), equivalent to its equally general integral version of eq. (43). It is important that in our description it is an intrinsic part of the law of conservation, balance, or symmetry of complexity that replaces various separated, biased and inconsistent extremum “principles” of unitary theory (like maximum entropy production, least action, etc.).

Due to the fundamental dynamic multivaluedness of all real interaction processes (see eqs. (1)-(16)), the permanent entropy-complexity growth in all real systems, objects and interaction processes emerges as the unique way to maintain the universal complexity conservation, or symmetry, thus resolving numerous contradictions between the entropy growth law and emergence of any quasi-regular object or dynamics within unitary (dynamically single-valued) theory. We see now that all real structures, however regular they may look or behave externally, consist of large numbers of very similar but still different realisations replacing one another in dynamically random order. This kind of behaviour determines the concept of extended, dynamically multivalued self-organisation, or self-organised criticality (SOC) in the general case of multiple complexity sublevels in many-body systems, leading to the unified quantitative criterion of the degree of chaos/regularity and related classification of all existing dynamical regimes and structures [1-3,10,11,13-15,19-22,28,29]. As follows from the main EP formalism expression for the unreduced interaction dynamics, eqs. (8), (9), the degree of chaoticity is universally determined by the chaoticity parameter $\kappa$ defined as

$$\kappa = \frac{\Delta \eta_i}{\Delta \eta_n} = \frac{\omega_z}{\omega_Q},$$

where $\Delta \eta_i = \Delta \eta_{ni}$, $\omega_z = \Delta \eta_i / \mathcal{A}_0$ and $\Delta \eta_n \sim \Delta \varepsilon$, $\omega_Q = \Delta \eta_n / \mathcal{A}_0$ are eigenvalue spacings and respective motion frequencies for “structural”, inter-element and internal, intra-element dynamics or other relevant kinds of system dynamics involved, while $\mathcal{A}_0$ is the characteristic action value.
If we start with the externally quasi-regular limiting regime of *dynamically multivalued self-organisation or SOC*, emerging at $\kappa \ll 1$, then we obtain a densely grouped realisation set, where one or few low-frequency “meta-realisations” (of the emerging higher complexity level) contain many closely spaced and quickly chaotically changing but externally (almost) unobservable elementary realisations, $N_r \sim N_{\text{SI}}$, $\alpha_r \sim 1$ in eq. (12b). As can be seen from eq. (9), in this case we obtain the approximately local, quasi-regular (single-valued) EP due to the quasi-independent summation over $i$ in the numerator of the EP kernel expression [1-3,10,11,28]. One should not forget, however, that although this dynamically single-valued approximation can be good enough in the SOC limit ($\kappa \ll 1$), the exact solution of eqs. (15)-(16) remains multivalued and thus internally chaotic, with important consequences, including *real time flow* and *universal growth of entropy-complexity* in any, even externally “ordering” structure-formation processes, which is to be compared with fundamentally incomplete conventional schemes of unitary, imitative self-organisation (see e.g. [71-88]).

Another important point of our extended vision of (multivalued) self-organisation regime at $\kappa \ll 1$ (or $\kappa \gg 1$, see below) is that it actually unifies the properly extended versions of various popular “ordered” regimes remaining separated in usual theory, including besides self-organisation itself, *self-organised criticality*, *synergetics*, *control of chaos*, *synchronisation*, *any control of any dynamics*, *mode locking*, and various *attractors*. We obtain thus the truly universal classification of all dynamic regimes in arbitrary systems in this limit of quasi-ordered structure, continuing then to other, more chaotic but equally unified regimes (see below). We also clarify numerous confusions and “difficult problems” in standard, unitary interpretation of each of those cases. Thus, we can confirm the “enslavement” principle of Haken’s “synergetics” [80-85] but in a much more transparent, universal formulation, adding essential chaoticity of the “enslaved” fast modes, which changes dramatically the involvement of the *entropy growth principle* already mentioned above and avoids various ambiguities about the necessity of “open” or “dissipative” system dynamics, etc. In a similar way, the presence of intrinsic, *fractally structured* chaoticity in this regime (in relation to the *dynamically probabilistic fractal* introduced above) clarifies persisting problems of usual SOC [86-88] and simultaneously shows that in reality *every* regime of self-organisation (dominating external regularity) is a case of that extended,
dynamically multivalued SOC (hence this our most comprehensive name for this dynamic regime). We show also that contrary to unitary scheme illusions [89-94], no control (or synchronisation) of any system can lead to real regularity and therefore the principle of realistic, complex-dynamical control itself should be essentially modified in favour of the symmetry (conservation and development) of complexity of the compound, both controlled and controlling, system [14,15,18-22] (see also below). As to the popular subject of attractors, our causally complete problem solution shows that any real system attractor is fundamentally “strange”, i.e. chaotic, but on the other hand, the real strange attractor structure is produced not by “exponentially diverging trajectories” of usual theory but by permanent, dynamically random realisation change, with power-law (rather than exponential) evolution of system state and structure [1,2]. Neither should one confuse conventional, unitary attractors created by system trajectory evolution with our plural, mutually incompatible realisations that form the structure of a real “strange attractor” (probabilistic fractal in real space) due to their permanent change in random order by transitions through the intermediate realisation of the wavefunction.

The opposite, strongly chaotic limiting regime of arbitrary system dynamics occurs at resonance between characteristic system frequencies or level separations, \( \Delta \eta_i = \Delta \eta_n \sim \Delta \varepsilon \), or \( \omega_x = \omega_Q \), and the chaoticity parameter \( \kappa \equiv 1 \) in eq. (55), providing thus the global chaos criterion. As can be seen from the main EP formalism equations (8)-(9), (15)-(16) (and the corresponding graphical analysis of refs. [1-4]), in that case the eigenvalues of individual realisations are so inseparably intermingled that they cannot be classified into quasi-independent groups unifying similar realisation configurations as it occurs in the opposite limit of self-organisation (\( \kappa \ll 1 \)), so that now, at \( \kappa \equiv 1 \), essentially different realisations replace one another at a not too high and not too low rate close to major system frequencies, \( N_r \sim 1 \), \( \alpha_r \sim 1/N_{\text{SR}} \ll 1 \). This kind of dynamics creates the situation of strongest possible chaotic fluctuations quasi-evenly distributed over the accessible motion space, whence the name of global, or uniform, chaos for this limiting regime. Correspondingly, the general EP and state-function expressions, eqs. (9), (16), show highly nonlocal, dynamically “smeared” features, far from their local approximations in the opposite, quasi-regular self-organisation regime.

Note also that the unified global chaos criterion, \( \kappa \equiv 1 \), reveals the genuine, deep meaning of the “well-known” phenomenon of frequency resonance.
in real, dynamically multivalued systems as the condition of strongly chaotic, “explosive” system behaviour (rather than only anomalous growth of the oscillation amplitude, in usual theory), which may lead to intense interaction development, with destruction of the former and creation of a new structure. The “resonant” meaning of strong chaoticity criterion becomes also physically evident (and therefore shockingly missing in usual theory): comparable mode frequencies increase dramatically “irreconcilable mode competition” that excludes the regularising “enslavement agreement” of self-organisation limit and inevitably leads to their endless chaotic replacement.

If the chaoticity parameter $\kappa$ grows well beyond the value of global-chaos transition, $\kappa \sim 1$, we obtain, at $\kappa \gg 1$, another quasi-regular, self-organised kind of dynamics, where now the slow intra-element motion “enslaves” the rapid inter-element dynamics and determines the emerging system behaviour usually having, however, more trivial nature, like spatially uniform (and small) energy-level shift. Therefore, a given initial system configuration determines the really interesting interval of $\kappa$ variation approximately between 0 and 1, where the system passes by the whole range of possible dynamic regimes, from (external) quasi-regularity of multivalued SOC at $\kappa \approx 0$ to global chaos at $\kappa \approx 1$.

Similar to the particular case of quantum (and eventually classical) chaos in periodically perturbed oscillator [1-3,14], in this arbitrary system case chaoticity growth from the self-organised external regularity at $\kappa \approx 0$ to the global chaos at $\kappa \approx 1$ occurs by uneven steps appearing each time $\kappa$ passes by a higher resonance condition at $\kappa \approx m/n$, with small integers $m, n, m < n$. One obtains thus the unified “fractal structure of chaos” (e.g. in a system parameter space or “phase space”) concentrating progressively around lower-degree resonances. This picture provides also the essential extension and generalisation of usual KAM theory applicable only to classical mechanical systems under condition of small perturbation of the trivial integrable system configuration (with the trivial result of preservation of its regular phase space structure for weak enough perturbation). In our extended version we can see what happens in a system of arbitrary origin and complexity level with arbitrary interaction (including quantum and classical mechanical systems), far from any integrable configuration. While the regular “tori” structure of the “phase space” (or corresponding parameter space) becomes ultimately smeared and unreal, the new, intrinsically chaotic (dynamically
multivalued) structure emerges, with its key features concentrating in the above fractal web around major frequency resonances [1,14].

As a result, we obtain the unified classification of all dynamic (fundamentally multivalued) regimes in any kind of system or process, varying between dynamically multivalued SOC and global (uniform) chaos depending on the chaoticity parameter $\kappa$ of eq. (55) that varies respectively between 0 and 1 (it can be further expressed through the detailed system parameters for each particular case) [1,2,9-11,13-15,18-22,28]. Moreover, the explicitly emerging character of all world structures obtained as a result of physically unified interaction process development implies the approximate intermittence of more regular, SOC-type and highly chaotic regimes, with their mutual transformation in fractally structured interaction development and complementary roles of rigid structural basis and chaotic search for further interaction development ways. The only essential addition to this picture is due to the special case of turbulence, providing a peculiar combination of highly ephemeral but still quite distinguishable structure features as a result of particularly small separation of complexity sublevels comparable to characteristic interaction parameter variation (e. g. in terms of action-complexity) for each complexity sublevel [1].

The described self-developing fractal structure of unreduced, dynamically multivalued (and therefore chaotically changing) interaction results realises the exponentially huge power of natural many-body interaction processes, which is the true essence of dynamic adaptation and “intelligent” structure creation phenomena explaining the “magic” properties of life, intelligence and consciousness [2,13-23,28]. The total realisation number $N_{\text{R}}$ of unreduced interaction dynamics in a real many-body system and thus its full operation power $P \propto N_{\text{R}}$ is determined by the number of combinations of its $N = N_{\text{unit}} n_{\text{link}}$ modes or essential interaction links (where $N_{\text{unit}}$ is the number of interaction elements and $n_{\text{link}}$ the average number of modes or interaction links per element):

$$P \propto N_{\text{R}} \approx N! \approx \sqrt{2\pi N} (N/e)^N \sim N^N.$$ (56)

Since $N$ is already a large number for many real systems, we obtain the exponentially huge operation power $P$ for such free-interaction system, including all its essentially quantum, chaotic, transitional and classical processes, as opposed to only power-law dependence of operation efficiency on
For any unitary, dynamically single-valued operation of traditional devices, \( P_0 \sim N^\beta (\beta \sim 1) \), \( P/P_0 \sim N^{N-\beta} \sim N^N \rightarrow \infty \). For a quite modest estimate of \( N \sim 10^3 - 10^4 \), we have \( N_{\Re}, P/P_0 \sim 10^{3000} - 10^{40000} \), which is to be compared with “ultimate” and “fundamental” estimates of \( P_0 \) for the most powerful unitary “quantum” computer of the entire Universe by the numbers of its bits \( \sim 10^{90} \) and ever performed operations \( \sim 10^{120} \) [95] and obviously yet much smaller values of ultimate capacities of a realistic in size unitary computer [96]. That huge difference between the greatest unitary imagination results and the natural, ordinary operation power of real, dynamically multivalued systems provides, in particular, the causal explanation of the “magic” (in usual theory) properties of life, intelligence and consciousness, taking into account that for both genome and human brain \( N \geq 10^{12} \) [2,14-22,28].

This exponentially huge efficiency of natural interaction adaptability is a consequence of the above universal symmetry of complexity (43) determining the probabilistically fractal structure of multivalued interaction dynamics, eqs. (8)-(16). In general, one obtains three such universal corollaries of the symmetry of complexity called complexity principles, which appear in applications and have particular practical importance [2,15,18-22]. These three laws are the complexity correspondence principle, the complex-dynamical control principle, and the unreduced (free) interaction principle.

The complexity correspondence principle implies essential or interesting complexity development mainly in interaction between systems of comparable complexity. In particular, a system of certain complexity can be efficiently simulated, controlled, designed, or modified only by a system of (reasonably) higher but not lower complexity.

The complex-dynamical control principle states that traditional regular control idea and result can never be realised in real system management because of inevitable dynamic multivaluedness of any controlling interaction result and should be replaced by suitable, progressive complexity development, in the form of entropy-complexity growth, eq. (43). Genuine sustainability of system dynamics implies thus its suitable chaotic changes and transformation, with growth or preservation of desired essential properties, instead of inevitable and often catastrophic degradation within usual, “protective” schemes of unitary control approach. This law becomes especially important in efficient design, management and control of today’s “globalised” world system dynamics of superior complexity level (see also below).
The unreduced (free) interaction principle refers to the above feature of exponentially huge power of dynamically probabilistic fractal operation, eq. (56), for natural, multicomponent interaction processes, as opposed to power-law efficiency of their conventional unitary models. In particular, this law underlies and explains the key features of life and intelligence always remaining mysterious within unitary theory but now acquiring quite realistic origin and new realisation possibilities in artificial nanobiosystems or macroscopic systems of genuine artificial intelligence and machine consciousness (see below).

We can proceed now with particular applications of the above unified complexity laws and features to various levels of progressively growing dynamic complexity, which demonstrate their causal completeness, wholeness and universality, leaving no place to unsolvable problems and growing contradictions of official science development (clearly appearing now as a result of specific, artificial limitations of just that, unitary science approach).

We have shown, in previous sections, how the unreduced interaction between two effectively structureless protofields gives rise to emerging, physically real elementary particles and all their causally specified properties, in the form of internally chaotic (dynamically multivalued) quantum beat processes. These causal particle properties include unified and causally complete quantum and relativistic dynamical features as manifestations of complex interaction dynamics, thus solving all respective unitary science “mysteries”, paradoxes and contradictions. The observed fundamental interactions between particles through the coupled protofield media (their perturbations) are also causally specified, in their intrinsically unified origin and dynamics, and they naturally give rise to the next emerging level of interaction complexity, including Hamiltonian interaction and genuine quantum chaos, quantum measurement phenomena and emergent intrinsic classical behaviour of elementary bound systems [1-11,14].

In the case of nondissipative particle interaction in a closed system we obtain the causally derived, complex-dynamical Schrödinger or Dirac equations (which are special cases of the universal Schrödinger formalism of eqs. (52), (54) at the lowest, quantum-mechanical complexity sublevels), including wave-particle duality and universal complex-dynamical mass definition without redundant Higgs-like entities. Many-body particle interaction entering those equations gives rise to the genuine quantum (Hamiltonian) chaos
involving true randomness of quantum interaction dynamics and passing consistently to respective classical chaos under the usual quasi-classical transition, $\hbar \to 0$ [1-3,10,11,13-15,44]. This result solves the stagnating unitary-theory problem of “absent” (genuine) quantum chaoticity due to the dynamic multivaluedness of unreduced interaction process, eqs. (2)-(16).

The quantum measurement situation corresponds to the same general kind of dynamically multivalued, intrinsically chaotic quantum behaviour but occurring in the presence of small dissipativity and system openness realising the measurement process development towards higher (eventually macroscopic) complexity levels [1,2,4]. The key point here is that the measured quantum object or system permanently performs its chaotic quantum jumps between the measured eigenstates even without (both before and after) any measurement interaction (i.e. in its closed, Hamiltonian state), thus actually taking all its “quantum possibilities” in causally random order, with respective dynamic probabilities (12) obeying the causally derived Born rule (13). The impossibility of such behaviour in any version of unitary theory forced to impose its “inexplicable” and heavily mystified “quantum postulates” or external influences (“decoherence” and “dynamic reduction” theories [97-103]) underlies the stagnating impasse of conventional quantum theory putting its obvious absence of elementary causality at the very basis of science, with all the massively studied quantum applications.

Finally, the simplest classical, permanently localised behaviour naturally emerges as a higher complexity sublevel of elementary bound systems, such as atoms, only due to their internal chaotic dynamics, without any external “decoherence” of unitary theory [1,2,7,8,10,14]. In this case the chaotic quantum-beat dynamics of each atomic bound system component strongly limits the whole system’s ability to perform larger sequence of quantum jumps in any given direction. This totally causal and intrinsic origin of classical behaviour as a higher level of interaction complexity naturally explains also the observed transient revivals of essentially quantum (undular) behaviour in interacting many-body systems, such as large molecule diffraction or superfluidity, directly contradicting all decoherence-based unitary theories.

The importance of this causally complete and problem-solving theory of complex interaction dynamics within a group of complexity sublevels from interacting elementary particles to atoms and their agglomerates is greatly amplified due to recent technological progress (real and promised) related
to quantum applications and nanobiosystems [13-15]. We should note, first of all, that our fundamental, causally derived conclusion of ubiquity of genuine quantum chaos in quantum interaction processes and systems (including their “pure”, totally Hamiltonian versions without any dissipativity) [1-3,10,11,13-15] implies practical impossibility of unitary quantum computers and any other quantum machines (even in the absence of any noise-induced decoherence), together with their promised magic efficiency deeply related to their dynamically single-valued, non-chaotic dynamic assumed in standard unitary theory. The same is true for any unreduced nanobiosystem dynamics, which will be close to essential chaoticity criterion, $\kappa \sim 1$ (see eq. (55)), at least for some its truly nanoscale interacting components, just due to their minimum sizes and maximum frequencies implied by the Bohr frequency origin [13-15]. In particular, the key operation processes of resonant excitations and quantum transitions correspond by definition to the global chaos condition $\kappa \approx 1$. Note also that ubiquitous quantum computing would contradict the universal complexity correspondence principle mentioned above [14,15].

However, the impossible high efficiency of unitary quantum machines can be recovered in another way in real, complex-dynamical (chaotic) quantum and classical nanobiosystems due to the exponentially huge efficiency of unreduced complex dynamics, eq. (56), and the related free interaction principle. Intrinsic system chaoticity is transformed here from a problem in unitary approach to advantage of unreduced interaction dynamics, actually realised in natural living systems and explaining the “magic” properties of life, intelligence and consciousness [13-22]. Similar features can now be reproduced in artificial and mixed nano-bio-structures, within properly organised “production lines”, from essentially chaotic processes with $\kappa \sim 1$ (quantum chaos, quantum measurement) to more regular, SOC-type output structure dynamics with $\kappa \ll 1$ (emerging complex-dynamic classicality of elementary bound systems), involving multiple transitions and switches between them. Hence e.g. the idea of the totally new, complex-dynamical nano-metal (and nano-solid-state) physics, where instead of macroscopic (and basically regular) manifestations of specific properties of metallic (or other solid-state) atom electrons for the bulk material properties, one will deal with the properly specified, complex nanoscale dynamics for individual interacting metal (and other) atoms, electrons and their agglomerates, similar to
biomolecule and biostructure dynamics in living organisms, with their superior efficiency. In fact, practically any sensible case of “strong interaction” in ordinary solid-state physics (including e.g. high-temperature superconductivity) appears now as unrecognised result of unreduced complex, dynamically multivalued interaction process [1,2].

The next higher group of unreduced dynamic complexity sublevels includes life-science applications specified by molecular and macroscopic bio-fractal structures, reliable complex-dynamical genomics and related ideas of causally complete, integral medicine [2,16-18,28]. They all use the exponentially huge efficiency of unreduced, multivalued many-body interaction dynamics, eq. (56), corresponding to the truly causal, reliable understanding of life dynamics, as opposed to strongly limited unitary guesses of the standard life-science framework always using its basically linear, one-way approach and logic. In particular, those real biological fractals of unreduced living system interactions and dynamics are quite different from unitary, purely mathematical fractals and realise the huge efficiency (56) of our dynamically probabilistic fractal [2,9-11,13-23,28] due to its universal symmetry of complexity (as opposed to the simplified “self-similarity” of usual fractals, only occasionally observed in external shapes of life).

Applying the concept of unreduced dynamically probabilistic fractal to genome interaction analysis, we arrive at the situation of reliable, causally complete genomics, where every smallest element of genome structure (its base pair) effectively interacts in average with any other one [16-18], thus realising the case of ultimately strong many-body interaction basically neglected in practical, purely empirical genome modifications. As a result, the latter practice of unitary logic application is close to almost blind manipulation with the extremely complex interaction network, which can only lead to catastrophic changes, in addition tending to accumulate in time due to relative system resistance to changes. Hence the idea of qualitatively extended, reliable complex-dynamical genomics considering all essential genome interactions [2,16-18,28]. This approach also properly explains and takes into account the role of large noncoding genome sequences, which appear now as the necessary vast interaction space ensuring the above exponentially huge efficiency of life dynamics.

The proposed causally complete genomics constitutes the necessary complex-dynamical basis for the objective understanding of living organism
dynamics, which further develops in the same form of dynamically multivalued interaction fractal to higher levels of biological structure complexity. The concept of integral medicine [2,16-18,28] implies the causally complete understanding of this entire complex-dynamical biofractal hierarchy, with respective visualisation of the multidimensional map of all its essential links and changes for each individual organism, providing its un-reduced, complex-dynamical structure that can now be treated in a truly reliable way (using the same causally complete, dynamically multivalued interaction analysis).

Further interaction complexity development in the same branch leads from living to intelligent and conscious systems. It is confirmed by rigorous and universal definitions of intelligence and consciousness within our un-reduced interaction analysis [2,19-22,28], obtained as emerging superior levels of the same unified dynamic complexity (14) that accounts for the (equally emerging) properties of life at its lower sublevels described above. While the unified complexity level of usual, empirical, or “animal”, intelligence is determined by (and actually is somewhat greater than) the un-reduced complexity level of the entire environment interacting with the intelligent system, the property of consciousness emerges from this minimum intelligence as a superior complexity level corresponding to well-defined, permanent bound-state emergence in the brain space of intelligent system (in rather exact similarity to classical behaviour emergence as elementary bound states of purely quantum objects at the lowest complexity levels, as described above). These complexity levels of intelligence and consciousness are realised in natural intelligent systems within their global interaction dynamics in the brain in the form of generalised quantum beat constituting either a nonlocal and highly chaotic “quantum” (undular and dualistic) kind of behaviour in the case of minimum, empirically driven intelligence or a more regular, SOC, or “classical” (permanently localised, trajectorial) behaviour in the case of genuine consciousness [2,19]. The universal Schrödinger equation for the generalised wavefunction, eq. (52), describes now the generalised quantum dynamics of the brainfunction $\Psi(\chi,t)$ in the space $\chi$ of entangled electro-chemical degrees of freedom of the brain [2,19].

These rigorous concepts of intelligent and conscious system dynamics, reproducing all essential features of respective behaviour types, are absolutely universal and do not depend on the physical (biological, artificial, or mixed) nature of the system, thus allowing for any application, including
artificial intelligence and machine consciousness [2,19]. The advantage of these unreduced concepts is that they reveal the dynamic origin and essence of all major manifestations of intelligent and conscious behaviour, as opposed to arbitrary guesses and huge simplification of usual, unitary approaches to artificial intelligence and consciousness, with the inevitable consequences for their realisation and use. And even in cases of limited practical realisation of pseudo-intelligent robotic, control and computer system behaviour, it is important to have the causally complete understanding of unreduced natural prototypes in order to properly design and develop those limited artificial-intelligence tools in exact correspondence to respective particular tasks and applications [19-22]. As complex computer, artificial intelligence and machine consciousness systems can be described as high-level control systems, there is the essential link here to the above complex-dynamical control principle, showing that unreduced complexity development elements should be used in efficient operation of any intelligent system.

The same causally complete understanding of complex interaction dynamics is equally indispensable to another group of applications to superior complexity levels including social and economic development problems of modern planetary civilisation and its local communities [1,2,23-26]. The universal complexity symmetry, in the form of permanent transformation of unreduced dynamic complexity $C$ from its hidden form of action-complexity $A$ to the explicit form of entropy-complexity $S$, eq. (43), provides the necessary fundamental, rigorous basis for these applications, whose absence in the standard unitary science framework (including all its “models” and imitations of complexity) leads to the characteristic non-causal, broken and contradictory state of knowledge in respective fields of economics, finance and development science. We thus discover, first of all, that the unified, unstoppable complexity development process of the world civilization and all its societies (their dynamic entropy growth) occurs in big steps, due to the fundamental discreteness of unreduced interaction process development. Correspondingly, the achieved causal understanding of characteristic features of each stage of this highly inhomogeneous process provides the universal, objectively specified guiding line for efficient development control and optimization, beyond any unitary-science guesses and subjective social interests.

It is shown, in particular, that the world complexity development has attained today the unprecedented and critical transition point, called
complexity, or sustainability, or globalisation, transition, or threshold, where the fundamental development instability and bifurcation point inevitably appear, after which the civilisation complexity development becomes highly globalised (strongly interactive at any scale) and cannot continue in the same, basically unitary (mechanistic, hierarchically split, profit-based and intrinsically unstable) way, irrespective of any efforts. It will instead either perform a stepwise growth to superior entropy-complexity level of harmonical system development (creative, distributed, reason-based and truly sustainable entropy-complexity growth without crises) or pass to the destructive, low-energy branch of dynamic entropy growth [1,2,23-26]. Based on our interaction complexity analysis, we specify respective changes in all major aspects of life (production, lifestyle and infrastructure, governance, knowledge role and development), together with the related efforts needed to establish the progressive development branch of harmonical system and avoid the dangerously growing (and the only existing) alternative of destructive branch of the naturally decaying unitary system. The universal complex-dynamical concept of generalised system birth, life, and death [1,2,23,24,28], together with the above unified complexity principles, is quite useful here, providing fundamentally substantiated, objectively optimal problem solutions for extremely complicated processes of global dynamics with huge numbers of ultimately diverse interaction participants.

This unreduced analysis of the world interaction processes show also that economic, or ecologic, or climate-related processes cannot (and should not) be separated from other development aspects, especially after the globalisation transition and world’s complexity threshold (situated around the last millennium border), so that respective, characteristically isolated fields of unitary science (economics, ecology, climate science, etc.) lose their meaning and any validity as such and must instead be included in the unified civilisation complexity analysis outlined here as its particular aspects that can develop progressively or destructively after the current bifurcation point only together with the entire global interaction system. In particular, application of the unified development and unreduced interaction analysis to economic aspects and features provides the universal and rigorously specified complex-dynamical concept of sustainable economic and financial risk management without crises and destructive losses [26]. We provide the exact definition of risk magnitude distribution in terms of entropy-complexity growth rate and
the respective dynamic equation for this quantity as a form of our generalised Hamilton-Jacobi formalism (51). Using this unified equation and its unreduced, dynamically multivalued solution (16), one can efficiently control risk evolution within the necessary sustainability borders for any economic and social system. In simpler situations of local system and enterprise dynamics at a given dynamic regime, one can also efficiently avoid dangerous instabilities of emerging chaoticity by using our unified criterion of global chaos around major system resonances, $\kappa \sim 1$ (see eq. (55)).

In summary, we obtain thus the naturally unified, causally complete and problem-solving picture of intrinsically complex (multivalued) world dynamics at all complexity levels, from elementary particles to consciousness and world development, with no place for any “hidden variables”, “dark matters”, inexplicable “mysteries” and “unsolvable” problems of unitary science, actually appearing due to its strongly missing dynamical content of plural and permanently changing system realisations. All related notions of nonintegrability (nonseparability), undecidability, or noncomputability emerge now as rigorously specified and unified versions of our universal dynamic randomness (chaoticity) and complexity determined by multiple, equally real but incompatible realisations (system configurations) produced in any unreduced interaction process within any real system or object. These notions appear not as unclear, separated, difficult and unsolvable features of simplified mathematical models of reality (as it occurs in unitary science) but rather as the unified key advantages of the unreduced world dynamics giving rise to all its “magic” properties and unlimited development possibilities to be used in applications. The latter include, in particular, the “edge research” agenda of unlimited but always causally complete complexity structure exploration even beyond the conventional material borders of reality [2]. While all “hidden” variables of artificially limited unitary knowledge are transformed into quite real structure of the multivalued fractal of world dynamics, the genuine borders of knowledge are pushed to infinity within its intrinsically complete version of the universal science of complexity.
References


