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What Do They Actually Probe at LHC?

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The existence of the omnipresent Higgs field providing the fundamental origin of elementary particle mass is the main theoretical concept behind the ongoing large-scale experiments at the LHC accelerator. We critically reconsider the properties of this concept of mass, noting that it contains many fundamental deficiencies and hard problems leaving serious doubts about this interpretation, without feasible progress in view. We then present another, dynamic and universal concept of mass avoiding these problems and thus opening a competitive new possibility for the LHC result interpretation. It is based on the unreduced, nonperturbative solution to (arbitrary) many-body interaction problem providing the universal origin of relativistic inertial and gravitational mass in the form of emerging complex (chaotic) dynamics within the properly specified elementary field–particle, thus rigorously completing the double-solution ideas of Louis de Broglie. As practically all other old 'mysteries' and new problems of fundamental physics are also naturally resolved within this unified complex-dynamic solution due to its essential mathematical novelty and provable completeness, we propose to consider it as a viable alternative possibility in interpretation of the LHC and other high-energy facilities' results.

Існування всюдисущого Хіґґсового поля, яке надає фундаментальне джерело маси елементарних частинок, є головною теоретичною концепцію триваючих широкомасштабних експериментів на прискорювачі ВАК. Ми критично переглядаємо властивості цієї концепції маси, відмічаючи, що її численні фундаментальні недоліки та тяжкі проблеми залишають серйозні сумніви щодо цієї інтерпретації, без передбачуваної можливости реального проґресу. Ми далі представляємо іншу, динамічну й універсальну концепцію маси, яка не має цих труднощів і, таким чином, відкриває конкурентоздатну нову можливість інтерпретації експериментів на ВАК. Вона ґрунтується на нередукованому, непертурбативному розв'язку задачі (довільної) взаємодії багатьох тіл, який дає універсальне джерело релятивістської інерційної та гравітаційної маси у вигляді виникаючої складної (хаотичної) динаміки всередині належним чином конкретизова-

ної елементарної поле-частинки, що у такий спосіб строго доповнює ідеї подвійного розв'язку Луї де Бройля. Оскільки практично всі інші старі «таємниці» та нові проблеми фундаментальної фізики також природнім чином вирішуються у цьому об'єднаному складно-динамічному розв'язку завдяки його істотній математичній новині та доведеній повноті, ми пропонуємо розглядати його як життєздатну альтернативну можливість у інтерпретації результатів ВАК та інших високоенергетичних установок.

Существование вездесущего поля Хиггса, дающего фундаментальный источник массы элементарных частиц, является основной теоретической концепцией продолжающихся широкомасштабных экспериментов на ускорителе БАК. Мы критически пересматриваем свойства этой концепции массы, отмечая, что многие её фундаментальные недостатки и трудные проблемы оставляют серьёзные сомнения относительно этой интерпретации, без видимой возможности реального прогресса. Мы представляем затем другую, динамическую и универсальную концепцию массы, которая избегает этих трудностей и открывает, таким образом, конкурентоспособную новую возможность интерпретации результатов БАК. Она основана на нередуцированном, непертурбативном решении задачи (произвольного) взаимодействия многих тел, дающем универсальный источник релятивистской инерционной и гравитационной массы в виде возникающей сложной (хаотической) динамики внутри должным образом конкретизированной элементарной поле-частицы, что таким образом строго дополняет идеи двойного решения Луи де Бройля. Поскольку практически все другие старые «тайны» и новые проблемы фундаментальной физики также естественным образом разрешаются в этом объединённом сложно-динамическом решении благодаря его существенной математической новизне и доказуемой полноте, мы предлагаем рассматривать его как жизнеспособную альтернативную возможность в интерпретации результатов БАК и других высокоэнергетических установок.

Key words: complexity, chaos, self-organisation, many-body problem, origin of time, origin of mass, Higgs field, relativity, quantum mechanics, Louis de Broglie's double solution, hidden thermodynamics, hierarchy problem, high-energy physics.

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1. WHAT ARE WE LOOKING FOR?

These days, after the triumphal announcement of the triumphant discovery of the 'officially expected' Higgs boson at the greatest accelerator factory of all times LHC [1, 2], it may be just the right time to try to understand the background, the purpose and the actual meaning of this huge effort at a deeper, more consistent level. Indeed, while this experimental search itself is concentrated on its well-elaborated empirical framework of 'smash and detect', the underlying ideas of fundamental world structure are far from any completeness, with a risk of being to-

tally misguided in interpretation of that tremendous experimental endeavour (even despite the actively discussed Nobel Prizes).

In this paper, we first provide a transparent non-technical description of limitations of the dominating interpretation of particle mass origin in the Higgs field [3–8] (sec. 2).

We then present a much more complete (presumably totally complete) framework of microworld structure and dynamics related to the ideas of founding fathers of new physics and providing a purely dynamic origin of mass, including its dynamically derived relativistic (special and general) properties [9–23] (sec. 3). Contrary to conventional theory, this causally complete description includes both inertial and gravitational aspects of mass, in their dynamically emerging equivalence. Other unifying aspects of the new framework additionally contribute to emerging picture consistency, including the origin and properties of (exactly four) fundamental forces, exactly three spatial dimensions and irreversibly flowing time, as well as other intrinsic and dynamic particle properties, such as electric charge, spin and now naturally unified, causally explained quantum and relativistic behaviour.

We proceed, in sec. 4, by the new consistent interpretation of all LHC efforts and the Higgs boson results within the proposed causally complete framework, which finally leads to the necessary important shift in accelerator research strategy, now well beyond arbitrary model assumptions and related wild empiricism. As a result, we definitely move thus towards a mathematically and experimentally consistent, physically real, unified and causally complete picture basically confirmed by all known observations (including cosmology and recent accelerator results) that would need then only further detail clarification within the already attained accelerator parameters, without resource waste and inefficient energy race implied by traditional theoretical scopes.

We finally argue, in sec. 5, that this intrinsically complete framework, originating in some less popular approaches by the founding fathers of modern physics, deserves comparison with the standard and other major interpretations of conducted tremendous experiments (also with other instruments), so as to enable at last the definite and optimal solution of old and accumulating new problems of fundamental physics. As we arrive today at practical, technical and economic, limits of such huge experimental efforts (let alone too numerous theoretical models), we must finally be able to derive a truly consistent and causally complete picture of the fundamental physical world construction, allowing also for the emerging real (*e.g.*, energy) problem solution, beyond usual 'infinite', always abstract and practically lost research agenda.

2. WHAT THE HIGGS IS GOING ON?

We start with a tentative list of fundamental deficiencies of the Higgs

field/particle concept (and thus also related to Standard Model particle theory), appearing already at the level of theoretical concept consistency, even before its direct experimental trial. We avoid easily accessible special references and technical details of this truly mainstream concept [1–8] being mainly of general fundamental interest here (thus further elaboration of details may be expected where it is necessary).

Thus, the Higgs field/particle concept reveals the following fundamental deficiencies (to be eventually compared to respective causally complete approach properties in sec. 3).

(1) A non-dynamic, mechanistic origin of mass (and other properties), by way of additional, 'vast', basically abstract entity introduction comparable to insertion of a new large dimension. This entity would inevitably produce not only the 'desired' but also other, unobserved and thus undesired properties that cannot be ignored (see below for details). As we shall see later (sec. 3), any non-dynamic origin of mass is unacceptable already because of the basic quality of its main inertia property and especially relativistic extensions of the latter.

(2) Manifestly non-universal origin of the universal property of mass to be further completed by various separated, artificial/special and quite technically complicated mechanisms for various particle species (see, *e.g.*, [24, 25]). Indeed, the Higgs field is directly introduced as a means to give finite mass to originally massless species of exotic W and Z bosons (transmitting weak interaction on a very small scale), while eventual extension of this mechanism to other particles (in a properly unified theory) would include many cumbersome and quite special details.

(3) This and other standard origins of mass directly refer only to elementary particles and become useless for compound, including macroscopic, bodies, in contradiction to classical, *e.g.*, relativistic effect, description (which can be considered as a separate aspect of (1) and (2)).

(4) It is not only non-dynamic (see (1)) but also basically non-chaotic, unitary mechanism of mass generation, which in itself contradicts the property of inertia truly compatible only with an internal chaotic (or 'thermal') dynamics like in the famous concept of 'hidden thermodynamics of (isolated) particle' by Louis de Broglie [26–29] (see sec. 3).

(5) A fundamental physical origin of mass should include a clear and universal explanation of relativistic mass behaviour, including mass–energy equivalence, which is not the case of the Higgs mechanism (and neither of other standard mechanisms for various elementary particles).

(6) There is no link between the origin of mass, a major intrinsic property of elementary particles, and their physical nature, remaining uncertain.

(7) Any fundamental origin of mass should include the basic mean-

ing of the (universal) 'quantity of matter', which is hardly the case for such (Higgs) mass generation. In particular, the origin and universality of mass/energy conservation appears uncertain.

(8) The same property/mechanism of mass refers to other particles and the Higgs boson itself, the latter being at the origin of mass (another manifestation of (1)).

(9) Normally, there should exist an additional interaction between particles through the Higgs field, which would variously influence many observed features, in contradiction to real observations. In particular, Higgs boson appear to be the unique boson species that does not transmit interaction but exists only for its own sake (which otherwise can be the case only for fermions). But contrary to fermions, it is not a matter-forming species and interaction source either. This is another series of manifestations of the artificial, mechanistic nature of the entire Higgs construction (see item (1)). In other words, 'symmetry-breaking' mass generation (justified by special demands of a particular abstract theory) can hardly be the only observable consequence of the Higgs field existence.

(10) Major limitation to only inertial manifestations of mass, its equally important (and universal) gravitational manifestations being ignored or left to separate mechanisms and additional entities, including thus the principle of equivalence and other fundamentally important implications. Knowing the underlying huge difficulties of (quantum) gravity inclusion into the Standard Model, it is easy to see that any such inclusion would change so much the existing schemes that hypothetical preservation of the same mechanism of mass generation looks quite illusive.

(11) Within this (or any standard) mechanism, there is no apparent origin of the main features of particle-mass spectra, including especially its observed limitation to electroweak scale (the hierarchy problem).

(12) And finally, we note that global, cosmological origin and properties of the omnipresent and everywhere homogeneous Higgs field remain inevitably dubious and will always need additional strong (and thus problematic) postulates within the already quite unstable Big Bang construction full of its own difficulties.

One may add that many of these difficulties will also persist for proposed non-Higgs mechanisms of mass-generating 'symmetry breaking' or other schemes of scholar theory within and beyond the Standard Model. Staggering non-universality is characteristic of mass origins proposed within the usual theory models (*e.g.*, [24, 25]), in striking contrast to the observed and needed absolute universality of all mass manifestations and relativistic properties. Therefore, an approach of another kind is necessary in order to definitely avoid these (and other related) problems, and we briefly review such a provably consistent de-

scription in the next section.

3. WHAT IS MASS, PARTICLE AND REALITY?

The desired deeper insight into the nature and purpose of today fundamental physical quest brings us back to the entire new physics endeavour beginning a hundred years ago. While the new-born disciplines of quantum mechanics, relativity and emerging field theory have progressively accepted in their officially established and always separated frameworks, their respective series of formally correct mathematical rules, artificially mystified postulates and abstract principles, leaving aside the true physical origin of the main entities and laws, a few founding fathers, such as Max Planck, Erwin Schrödinger and Louis de Broglie persisted in their 'stubborn' efforts to find the unified, physically real and truly consistent basis for the emerging microworld reality.

In particular, Louis de Broglie, the discoverer of the most 'mysterious' quantum feature of wave–particle duality and related formula for the length of 'particle wave' inquired from the very beginning [30–33] into the unreduced dynamics of tangible physical entities liberated from any supernatural mystification [34–36]. Extended through a turbulent half-century, the difficult and contradictory intellectual opposition to the dominating abstract approach [37] had finally brought him to the 'double solution' concept [38, 39] trying to provide the causally complete foundation for quantum mechanics but inevitably involving also the physical origin of elementary particles and their intrinsic properties, such as wave and mass. As a result, a simple elementary particle like an electron appeared as a nonlinear 'peak' of the surrounding quasi-linear smooth field, moving in its carrying wave but also performing permanent 'thermodynamic' (chaotic) motions accounting for particle mass and its relativistic transformation. This '(hidden) thermodynamics of isolated particle' [26–29] have extended the causally interpreted wave–particle duality to the basis for a still somewhat incomplete and locally contradictory but generally realistic and unified picture of particle origin and dynamics. While this causal description attempt is either totally ignored by the mainstream approach or strongly simplified down to separated formal schemes (like 'pilot-wave theory'), today, we are brought back to the necessity of the physically and mathematically consistent theory of particle structure and properties [9–11, 13] actually completing the unreduced version of those double solution ideas of Louis de Broglie.

Contrary to positivistic formal description of observed results of occurring processes, our search for the consistent origin of particle properties naturally starts from the unified source of those processes that can be only due to the simplest possible interaction between the

minimum number of omnipresent and initially structureless observed entities. Thus, we start with two homogeneous, uniformly interacting (mutually attracting) primordial media, or (tangible) 'protofields', the electromagnetic (e/m) and gravitational ones, further specified later and eventually giving rise to respective observed long-range interactions and fields, as well as local structures observed as particles. There is no other, redundant entities, postulated laws, simplified 'models' or abstract 'principles' in this approach, and we rigorously derive instead the intrinsically unified particle/field origin, dynamics, internal properties and all (correct) laws only due to unreduced, universally nonperturbative analysis of this underlying complex-dynamic, structure-forming interaction process [9–12, 16–19, 22, 23].

A provably universal and quite general Hamiltonian description of that underlying interaction between two protofields takes a familiar form termed 'existence equation' in this case [9–12, 16–18, 22, 23]:

$$\left[h_{\mathrm{g}}(\xi) + V_{\mathrm{eg}}(\xi, q) + h_{\mathrm{e}}(q) \right] \Psi(\xi, q) = E\Psi(\xi, q) \,, \qquad (1)$$

where $\Psi(\xi, q)$ is the compound system state-function totally describing its configuration; $h_{\mathrm{g}}(\xi)$ and $h_{\mathrm{e}}(q)$ are the generalised Hamiltonians for non-interacting gravitational and e/m protofields, respectively; $V_{\mathrm{eg}}(\xi, q)$ is their (attractive) interaction potential, and E—the Hamiltonian eigenvalue (generalised energy) for the resulting system configuration. Note that these protofield Hamiltonians and their interaction can naturally be further specified to include all detailed interactions between individual protofield elements [22, 23], but there is no immediate need to do it explicitly as this won't change the form and major results of our analysis, the more so that while certainly having definite internal structures (generally specified later), the protofields are considered basically structureless at this stage and instead giving rise to all observed world structures. Although the Hamiltonian form of this starting equation resembles among others the classical Hamilton–Jacobi equation or quantum-mechanical Schrödinger formalism, we do not really use any of these as the basis for our description and rather show later, in the emerging formalism of universal dynamic complexity [9, 18, 23, 40–42], that this is indeed the universal form of any interaction description, with a new, deeper and physically specified meaning of participating quantities. In particular, the generalised Hamiltonians and energy emerge as expressions of a differential measure of unreduced dynamic complexity (see below). Note also that using any special (and always limited) 'models' for this interaction Hamiltonians and potential would hardly be useful at this stage, since the detailed protofield properties remain basically unknown and cannot be directly measured within this world totally emerging as a result of this interaction development.

The existence equation, Eq. (1), can be conveniently analysed in terms of eigen-solutions for the Hamiltonian $h_e(q)$ of a system component, the e/m protofield, leading to an equivalent system of equations:

$$\left[h_g(\xi) + V_{nn}(\xi)\right]\psi_n(\xi) + \sum_{n'\neq n} V_{nn'}(\xi)\psi_{n'}(\xi) = \eta_n\psi_n(\xi)\,, \qquad (2)$$

where $\psi_n(\xi)$ and η_n are state-function components and eigenvalues to be found, and $V_{nn'}(\xi)$ are matrix elements of the interaction potential [9–12, 16–19, 22, 23]. Generally, the system of equations (2) is as non-integrable as the starting Eq. (1) and usual theory approach would consist in replacing this nonintegrable problem with a 'close' but integrable one such as

$$\left[h_g(\xi) + V_{nn}(\xi)\right]\psi_n(\xi) = \eta_n\psi_n(\xi)\,. \qquad (3)$$

The underlying (unproved) assumption is that the exact solution of this integrable problem is also close enough, at least qualitatively, to that of the unreduced problem of Eqs. (1), (2). It is evident, however, that the latter is qualitatively different from the simplified version of Eq. (3) by numerous entangled and 'propagating' links between state-function components $\psi_n(\xi)$. Using the generalised effective potential method [9, 20, 43], we further specify this difference and reveal the qualitatively new features of the unreduced interaction problem solution just leading to the desired universal origin of elementary particles, their relativistic mass and other intrinsic and dynamic properties [9–23].

If we do not simplify anything in the unreduced interaction problem formulation of Eqs. (2), but try instead to arrive at its 'integrable' form by the generalised method of exclusion of variables expressed with the help of the Green function [9, 20, 43, 44], then we obtain a seemingly 'integrable' equation for only one state-function component,

$$\left[h_g(\xi) + V_{\text{eff}}(\xi;\eta)\right]\psi_0(\xi) = \eta\psi_0(\xi)\,, \qquad (4)$$

where $\eta = \eta_0$ and the *effective potential* (EP) $V_{\text{eff}}(\xi;\eta)$ actually contains the unreduced problem complexity in a compact form of nonlinear dependence on the eigenvalues (η) and eigenfunctions to be found:

$$V_{\text{eff}}(\xi;\eta)\psi_0(\xi) = V_{00}(\xi)\psi_0(\xi) + \sum_{n,i} \frac{V_{0n}(\xi)\psi^0_{ni}(\xi)\int_{\Omega_\xi} d\xi'\psi^{0*}_{ni}(\xi')V_{n0}(\xi')\psi_0(\xi')}{\eta - \eta^0_{ni} - \varepsilon_{n0}}\,, \qquad (5)$$

with $\varepsilon_{n0} = \varepsilon_n - \varepsilon_0$ ($\varepsilon_n, \varepsilon_0$ are eigenvalues of the free e/m protofield Hamiltonian $h_e(q)$); $\{\psi^0_{ni}(\xi)\}$, $\{\eta^0_{ni}\}$ —complete sets of (unknown) eigenfunctions and eigenvalues for a system of equations similar to Eqs. (2) but of smaller dimensionality and $n \neq 0$ [9, 10, 16–18, 22, 23].

It is not difficult to see, due to this nonlinear EP dependence on the

eigenvalues to be found, the eigen-solution number $N_{\max}$ of the effective existence Eq. (4) (equivalent to the unreduced problem of Eqs. (1), (2)), is many times greater than the 'ordinary' one extended (incorrectly) from perturbative models like Eq. (3) [9, 10, 16–18, 22, 23]:

$$N_{\max} = N_{\xi}\left(N_q N_{\xi} + 1\right) = N_{\Re} N_{q\xi} + N_{\xi}\,, \tag{6}$$

where N_q and N_{ξ} are the numbers of terms in the sums over *n* and *i* in Eq. (5) (usually, $N_q = N_{\xi} = N$ —the number of interacting degrees of freedom), $N_{q\xi} = N_q N_{\xi}$ is the 'ordinary' eigen-solution number for a physically complete system configuration substituted (incorrectly) for $N_{\max}$, and $N_{\Re} = N_{\xi}$ is the number of system realisations, *i.e.* of its really emerging, equally possible configurations, each of them corresponds to a physically complete 'ordinary' eigen-solution number. The relation of Eq. (6) clearly implies then that the unreduced system dynamics driven by the same interaction consists of permanent, unceasing process of realisation change 'chosen' by the system itself in a truly and causally random order thus defined. The last term of a reduced eigenvalue number N_{ξ} in Eq. (6) corresponds to a special, 'main' or 'intermediate', system realisation necessarily taken by interacting components during system transition between its two consecutive 'regular' realisations as a result of component rearrangement. This intermediate realisation contains transiently quasi-free interaction components (hence, its reduced eigenvalue number) and represents the causally complete, physically real extension of the quantum-mechanical wavefunction [9–11, 15–19, 22, 23]. Note that all these conclusions and the unreduced solution structure are confirmed by the independent graphical analysis of the same problem [9, 20].

The *dynamic* probability of each *r*-th causally random realisation emergence, α_r, is then derived as

$$\alpha_r = \frac{1}{N_{\Re}} \text{ with } \sum_r \alpha_r = 1\,, \tag{7}$$

and generalised as $\alpha_r = N_r / N_{\Re}$ for compound realisation structure at higher complexity levels, with N_r elementary realisations within the *r*-th actually observed realisation. We thus obtain a universally valid and now consistent concept of *dynamical chaos* (including *genuine quantum chaos* [9, 18, 20, 22]) closely related to equally *universal* concept of *dynamic complexity*, *C*, defined as any growing function of the number of system realisations (or related rate of their change) equal to zero for the unrealistic case of only one realisation (exclusively considered in usual theory) [9, 18–20, 23, 40–42]:

$$C = C(N_{\Re})\,,\ dC/dN_{\Re} > 0\,,\ C(1) = 0\,, \tag{8}$$

with, for example, $C(N_{\Re}) = C_0\left(N_{\Re} - 1\right)$ or $C(N_{\Re}) = C_0 \ln(N_{\Re})$ [1]. It is important to note that, whereas in any real situation $N_{\Re} > 1$ and most often $N_{\Re} >> 1$, any usual exact-solution or perturbative theory analysis (including scholar chaos and complexity concepts) corresponds to $N_{\Re} = 1$, implying strictly zero value of genuine dynamic complexity and absent true chaoticity (which does not exclude their imitations). Whereas real, dynamically multivalued interactions and structures emerging from them (starting from elementary particles) are *always* internally chaotic (dynamically random) and complex $(N_{\Re} > 1)$, their dynamically single-valued, or *unitary*, images in usual theory are basically regular and non-complex $(N_{\Re} = 1)$, though maybe appearing externally 'intricate' and 'irregular'.

We can further specify the emerging system configuration (interaction result) for our concrete system of two coupled protofields. The measured *system density* $\rho(\xi, \boldsymbol{Q})$ in the unreduced EP formalism of Eqs. (4), (5) is given by the *dynamically probabilistic* sum (marked by $\oplus$ sign) of densities $\rho_r(\xi, \boldsymbol{Q})$ of all chaotically changing realisations [9, 10, 16–19, 22, 23]:

$$\rho(\xi, \boldsymbol{Q}) \equiv \left|\Psi(\xi, \boldsymbol{Q})\right|^2 = \sum_{r=1}^{N_{\Re}} {}^{\oplus} \rho_r(\xi, \boldsymbol{Q}) = \sum_{r=1}^{N_{\Re}} {}^{\oplus} \left|\Psi_r(\xi, \boldsymbol{Q})\right|^2 , \tag{9}$$

$$\Psi_r(\xi, \boldsymbol{Q}) = \sum_i c_i^r \left[\Phi_0(\boldsymbol{Q}) \psi_{0i}^r(\xi) + \sum_{n,i'} \frac{\Phi_n(\boldsymbol{Q}) \psi_{ni'}^0(\xi) \int\limits_{\Omega_\xi} d\xi' \psi_{ni'}^{0*}(\xi') V_{n0}(\xi') \psi_{0i}^r(\xi')}{\eta_i^r - \eta_{ni'}^0 - \varepsilon_{n0}} \right], \tag{10}$$

where $n \neq 0$; $\Phi_0(\boldsymbol{Q})$, $\Phi_n(\boldsymbol{Q})$ are (known) eigenfunctions of the e/m protofield Hamiltonian $\hat{h}_e(q)$; c_i^r are matching coefficients related to causal Born's rule for realisation probabilities [9, 10, 16–19, 22, 23] and $\{\psi_{0i}^r(\xi), \eta_i^r\}$ are the r-th realisation eigen-solutions of the effective existence equation, Eqs. (4), (5). If we make the proper choice of the e/m protofield eigenfunctions $\Phi_0(\boldsymbol{Q})$, $\Phi_n(\boldsymbol{Q})$ in the form of narrow peaks corresponding to its actual (though maybe unknown and practically indiscernible) elements, then we can see from Eqs. (5), (10) that each r-th emerging realisation tends to concentrate around a particular eigenvalue η_r^r interpreted as emerging space coordinate [9–11, 16–19, 22, 23]. As complex interaction dynamics consists in unceasing realisation change in random order, it means that protofield attraction

[1] In this universal complexity definition, 'realisation' means any system realisation, including the special intermediate realisation of the generalised wavefunction (or distribution function), contrary to our usual realisation number $N_{\Re}$ from Eq. (6) including only regular, 'localised' realisations containing the complete eigenvalue number. However, one can hardly have any confusion here as practically always $N_{\Re} >> 1$.

ends up in a permanent process of alternating protofield squeeze (with entanglement) and extension (with disentanglement) around different centres randomly chosen in the vicinity of certain, also eventually arbitrary locations (separated by larger distances).

We call each such local, *spatially chaotic* (dynamically multivalued) process of permanent nonlinear pulsation of coupled protofields as the *quantum beat* and argue that it forms the essential dynamical structure and physical origin of properties of a simple *elementary particle*, or (thus intrinsically dualistic) *field–particle*, such as the electron. Compound particles are constituted by a number of such (variously) mixed processes. Note that complex quantum-beat dynamics of the coupled protofields thus derived by our unreduced interaction analysis has a clear physical origin in the form of evident system instability with respect to self-amplifying local deformation and squeeze followed by extension and the next squeeze, each time around a randomly chosen centre [9–11, 16–19, 22, 23].

This complex quantum-beat dynamics also realises the universal mechanism of physically real space and time emergence as a result of unreduced interaction development. A highly inhomogeneous local protofield squeeze in the initially totally homogeneous system of two coupled protofields gives rise to the fundamental, naturally discrete and tangible physical space structure dynamically 'woven' from two entangled protofields, while permanent dynamically random change of the dynamical squeeze centre (system realisation) is the clearly specified origin of unceasing and irreversible time flow. Specifically, the emerging physical space point size r_0 is given by the characteristic eigenvalue separation for a regular realisation of the effective existence equation, Eqs. (4), (5), $r_0 = \Delta x_i = \Delta_i \eta_i^r$, while the elementary length λ of the same complexity level is given by the characteristic eigenvalue separation of two different, neighbouring realisations, $\lambda = \Delta x_r = \Delta_r \eta_i^r$. Elementary time interval τ is naturally obtained as the quantum-beat period, $\Delta t = \tau = 1/\nu$, with ν standing for its frequency measuring the intensity of its spatially chaotic realisation change process. Its value can be derived from that of the above elementary length λ (obtained from solution of Eqs. (4), (5)) and υ_0, the excitation propagation speed for the (coupled) e/m protofield material, $\tau = \lambda/\upsilon_0$, where this speed is naturally identified with the speed of light c, $\tau = \lambda/c$, since the e/m protofield excitations are observed as photons. We obtain thus the clearly specified physical origin of space (naturally quantised due to realisation discreteness) and time (permanently and irreversibly flowing due to spatially chaotic realisation change) in the same quantum-beat process that forms the field–particle structure [9–11, 16–19, 22, 23].

As physically real space and time are made by system realisation change, while dynamic complexity is determined by realisation number and rate of change, a basic integral *complexity measure* is provided by

the simplest combination of these dynamically emerging space and time elements, action-complexity $\mathcal{A}$, extending the usual mechanical action concept and actually expressing the number of realisations progressively taken by the system [9, 11, 16–19, 22, 23, 40–42]:

$$\Delta\mathcal{A} = p\Delta x - E\Delta t\,, \tag{11}$$

where coefficients p and E are recognised as (generalised) *momentum* and *energy*, which can be interpreted thus as *differential* complexity measures (realisation change rates):

$$p = \frac{\Delta\mathcal{A}}{\Delta x}\Big|_{t=\text{const}} \cong \frac{\mathcal{A}_0}{\lambda}\,, \tag{12}$$

$$E = -\frac{\Delta\mathcal{A}}{\Delta t}\Big|_{x=\text{const}} \cong \frac{\mathcal{A}_0}{\tau}\,, \tag{13}$$

with the characteristic action value $\mathcal{A}_0$, and x, p generally expressed by vectors.

It becomes clear that at the lowest complexity levels considered this characteristic value of action-complexity is given by the Planck constant h, $\mathcal{A}_0 = h$, which reveals its physically real, *dynamic origin* as the fundamental *quantum of action-complexity* and explains its *finite value* (realisation discreteness) and *universality* at all those *lowest* complexity sublevels [9, 11, 14, 16–19, 22, 23]:

$$E = -\frac{\Delta\mathcal{A}}{\Delta t}\Big|_{x=\text{const}} = \frac{h}{\tau} = h\nu\,. \tag{14}$$

For the state of rest ($p = 0$) of the elementary particle specified now as a quantum-beat process, one derives thus the following expression for its rest energy:

$$E_0 = \frac{h}{\tau_0} = h\nu_0 \tag{15}$$

coinciding with the famous de Broglie's conjecture [30–33] that leads to the idea of wave–particle duality and the particle wavelength expression, but now with a totally specified origin of the 'periodic phenomenon' and related duality within the elementary field–particle (quantum beat) constituting its physical nature. As the rest energy E_0 in Eq. (15) is a (differential) complexity measure of spatially chaotic reduction and extension cycles of quantum beat, the latter can be characterised as a random wandering of the 'flickering' squeezed state, or virtual soliton, of a particle within its (physically real) wavefunction, giving rise to the property of inertia, in agreement with de Broglie's hidden thermodynamic concept [26–29]. Particle (or actually any object) inertia is there-

fore due to its internal multivalued (chaotic) dynamics, so that its partial ordering for the global motion in certain direction meets a finite 'resistance' of this 'hidden thermostat' trying to preserve its internal motions' 'temperature'. Instead of direct introduction of mass measuring thus explained inertia, we shall better try to derive this key property in a more rigorous way from global motion dynamics.

We can now rigorously define the state of rest of an isolated system as the one with the lowest (always positive) value of its energy-complexity E (as defined by Eq. (13)) and the state of (any global) motion as anyone with the energy-complexity value greater than the minimum of the state of rest [9, 11, 16–18, 23]. The state of rest is characterised by the most homogeneous distribution of dynamic realisation probabilities, Eq. (7) (totally homogeneous one for an elementary field–particle at rest), also called uniform chaos, while the state of motion is realised as a less uniform distribution of realisation probabilities within the partially ordered, or self-organised, dynamics where the direction (probabilistic tendency) of this global motion is determined by higher values of respective realisation probabilities. Correspondingly, action-complexity $\mathcal{A}$ for an elementary field–particle at rest does not contain any space (coordinate) dependence and acquires such dependence on (emerging) space coordinate for a moving particle, $\mathcal{A} = \mathcal{A}(x, t)$, so that

$$\frac{\Delta\mathcal{A}}{\Delta t} = \frac{\Delta\mathcal{A}}{\Delta t}\Big|_{x=\text{const}} + \frac{\Delta\mathcal{A}}{\Delta x}\Big|_{t=\text{const}} \frac{\Delta x}{\Delta t} = pv - E\,,$$

or

$$E = -\frac{\Delta\mathcal{A}}{\Delta t} + pv = \frac{h}{\mathrm{T}} + \frac{h}{\lambda} v = h\mathrm{N} + pv\,, \tag{16}$$

where the total energy E of a moving field–particle is given by Eq. (14), and its global-motion momentum p universally defined by Eq. (12) is now specified as

$$p = \frac{\Delta\mathcal{A}}{\Delta x}\Big|_{t=\text{const}} = \frac{h}{\lambda}; \tag{17}$$

v is the global motion velocity:

$$v = \frac{\Delta x}{\Delta t} = \frac{\Lambda}{\mathrm{T}}; \tag{18}$$

$\tau = \Delta t\big|_{x=\text{const}}$ is the quantum-beat (realisation-change) period measured at a fixed space point; $\lambda = \Delta x\big|_{t=\text{const}}$ is the fixed-time size of spatial inhomogeneity emerging in the average, global part of moving system structure, $\Delta t = \mathrm{T}$ and $\Delta x = \Lambda$ are the 'total' quantum-beat period

and space inhomogeneity ($\mathrm{N} = 1/\mathrm{T}$ is the respective frequency) [9, 11, 16–18, 23].

The complex-dynamic total energy partition of Eq. (16) and related expression for the global motion momentum of Eq. (17) provide the new, causally complete insight into the structure of unreduced motion dynamics. The latter contains the proper global, externally regular (though internally chaotic) motion tendency given by the second summand, pv, in the total energy partition of Eq. (16). Its first summand, $h\mathrm{N}$, describes the complementary tendency of totally random system deviations from that global motion tendency (here chaotic wandering of particle virtual soliton). Moreover, Eq. (17) shows that there is an emerging structure with the characteristic length λ associated with the global motion, which is easily recognised in our case as particle *de Broglie wave* with the wavelength $\lambda = \lambda_B = h/p$. There is nothing mysterious thus in this *emergent wave–particle duality* phenomenon, being a manifestation of the universal complex-dynamical structure-formation process within the system global motion. The global-motion tendency emerges as more frequent chaotic jumps (here, of the virtual soliton) between system realisations with similar configuration (undular shape of interacting protofields for this case).

There is a direct link here to the above property of inertia, as the dynamically multivalued interaction process 'resisting' to the externally imposed motion tendency becomes 'corrugated' in proportion to its complex-dynamic inertia and performs that global motion in a 'caterpillar' fashion. Since the (dynamically multivalued) system cannot avoid performing those inertial chaotic deviations around its global motion tendency, the velocity v of the latter will always be smaller than the speed of any single jump between realisations occurring at the speed of perturbation propagation in the interacting component material, $v_0 = c$, the speed of light thus causally introduced (without any abstract postulates) for our case of e/m protofield coupled to the gravitational protofield, together with the corresponding 'relativistic' limitation, $v < c$ [12, 13, 16–18, 23]. To obtain a quantitative relation, note that, during a period of one jump within the global motion tendency, $\tau_1 = \lambda/c$, the system (virtual soliton) should perform $n_1 = c/v$ jumps of duration τ (from Eq. (14)) of totally random deviation from that tendency. Thus, $\tau_1 = n_1\tau$, 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 de Broglie wavelength derivation [33] that does not take into account the chaotic, multivalued part of particle dynamics. It remains to insert the definitions of τ and λ, Eqs. (14), (17), into the obtained relation, and we obtain the famous *relativistic dispersion* formula:

$$p = E\frac{v}{c^2} = mv, \tag{19}$$

which provides the desired *rigorous* definition of inertial mass–energy-complexity, $m = E/c^2$ [12, 13, 16–18, 23]. We can return now to the state of rest, where $E_0 = m_0 c^2$, with m_0 being the *dynamically defined* rest mass of the quantum-beat process, so that the basic relation of Eq. (15) postulated by de Broglie [30–33] can be rewritten in its complete form

$$E_0 = m_0 c^2 = h\nu_0 . \qquad (15')$$

In the same way, the dynamically determined inertial mass–energy for a state of motion is obtained from Eq. (14) as the *spatially chaotic* quantum-beat frequency:

$$E = mc^2 = h\nu = \frac{h}{\tau} . \qquad (14')$$

Even though our complex-dynamic mass definition is not yet complete in all its aspects (to follow below), we can already at this stage certify the rigorously substantiated absence or natural solution of problems (1)–(8) of Standard-Model mass concept involving the Higgs field (sec. 2). In particular, one can emphasize the universality of the above mass–energy definition as temporal rate of (spatially) chaotic realisation change of (all) underlying interaction processes, in their unreduced, dynamically multivalued version, Eqs. (11)–(19). Inertia and (generally relativistic) mass–energy of a system is therefore a major manifestation and (differential) measure of unreduced dynamic complexity of all system interactions (where one can often exclude certain complexity levels, which are not involved in particular observations, *e.g.*, in nonrelativistic mechanics).

In close relation to these basic properties of mass, there is the 'evident' (actually postulated in usual theory) but now *rigorously derived* relation of Eq. (19), $p = mv$, which is equivalent to *laws of Newtonian mechanics*, now not simply postulated (yet since Newton) but mathematically derived in their nontrivial complex-dynamic and relativistic content (totally lost in usual version). Newton's second law is obtained by taking (generally discrete) time derivative of this relation, with now causally complete physical meaning of mass, energy, momentum, space and time in terms of complex (multivalued) dynamics of all underlying (protofield and higher-level) interaction processes. This degree of rigour and universality is impossible for the Higgs and other non-dynamic, new entity-dependent mechanisms.

We proceed by inserting the basic relation of Eq. (19) into the causal particle wavelength definition of Eq. (17) to obtain the familiar but now causally complete expression for the de Broglie wavelength within the physically real version of wave–particle duality (due to the dynamically multivalued quantum-beat process):

$$\lambda = \lambda_B = \frac{h}{m\upsilon}. \tag{20}$$

For a particle at rest, one can further derive the length of its virtual soliton jump (with the speed of light, c) by noting that the quantum-beat frequency $\nu_0 = m_0 c^2 / h$ from Eq. (15′) corresponds to the wavelength

$$\lambda_0 = \frac{c}{\nu_0} = \frac{h}{m_0 c}, \tag{21}$$

which could be obtained from Eq. (20) with formally incorrect but physically understandable parameters $m = m_0$, $\upsilon = c$. For the electron with the rest mass $m_0 = m_e$, the length λ_0 of virtual soliton jump between two 'corpuscular' (squeezed) quantum-beat realisations coincides with the Compton wavelength λ_C, providing thus its additional interpretation in terms of internal (complex) dynamics of isolated electron (see also below):

$$\lambda_C = \frac{h}{m_e c}. \tag{21′}$$

Due to the fundamental link between mass–energy and time, Eq. (14), the complex-dynamic dispersion relation of Eq. (19) has further consequences for time relativity. Substituting Eq. (19) into the energy partition relation of Eq. (16) and using Eq. (14), we obtain the causally explained expression for *time relativity* as relation between the externally and internally measured time (quantum-beat) periods τ and T for a moving particle:

$$\tau = T\left(1 - \frac{\upsilon^2}{c^2}\right). \tag{22}$$

We can clearly see here the *physically real, complex-dynamic origin* of time relativity (as opposed to formal relativity postulates in standard theory) [9, 11–13, 16–18, 23]. As it is the same complex-dynamic quantum-beat process that gives rise to both physically real clock 'ticking' (by the totally random tendency, first summand in Eq. (16)) and particle global motion (by the partially ordered tendency, second summand in Eq. (16)), the internal system clock will slow down with growing global motion speed υ, $T > \tau$, because an ever greater part of the total energy will go from the former (clock) to the latter (motion). Due to universality of our time and mass–energy concepts, this result remains valid for any real clock size and mechanism (thus resolving another 'mystery' of usual theory).

In order to get the standard, directly measurable expression for thus

causally derived time relativity, we shall use a supplementary relation between T, τ and the rest-frame quantum-beat period τ_0 or respective frequencies N, ν and ν_0:

$$N\nu = (\nu_0)^2 , \; T\tau = (\tau_0)^2 . \tag{23}$$

This relation expresses a physically transparent manifestation of conservation of system realisation number measured by frequencies, which is a version of the universal complexity conservation law [9, 11–13, 16–18, 23]. Excluding not directly measurable τ from Eq. (22) with the help of Eq. (23), we obtain the familiar expression of time relativity, but where both time and its relativity regain their physically real and universal origin:

$$T = \frac{\tau_0}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} , \; N = \nu_0 \sqrt{1 - \frac{\upsilon^2}{c^2}} . \tag{24}$$

Using this causal time relativity expression together with Eqs. (19) and (15) in Eq. (16), we arrive at the *causally explained mass relativity*:

$$m = \frac{E}{c^2} = \frac{m_0}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} . \tag{25}$$

It further extends our complex-dynamic mass concept (cf. item 5 in sec. 2) and implies that *any* global, externally regular motion is realised only as a partially ordered tendency of *dynamically random* system jumps between realisations, where each jump even within this 'self-organised' global tendency is performed probabilistically (with a greater probability to fall within this tendency).

We can now proceed with other dynamically emerging features of the same unreduced process of protofield interaction completing the consistent picture of observed particle properties and behaviour and in particular solving the remaining problems of sec. 2. We start with explaining the observed number of global space dimensions, $N_{\text{dim}} = 3$, as being due to the global realisation number of protofield interaction equal to the number of interacting entities (see above, after Eq. (6)), two protofields plus the coupling interaction itself. In general, a universe emerging from n protofields coupled by m (global) interactions should have $N_{\text{dim}} = n + m$ global space dimensions showing already that each additional fundamental entity implies an additional space dimension. It is important that our physically real space emerges as tangible complex-dynamic entanglement of interacting entities, where

the observed similarity between spatial dimensions implies an equally globally homogeneous and direct mixture of interacting entities, without a 'special', separated status of any entity.

Now, this protofield interaction process with N_{dim} global realisations (space dimensions) splits, as we have seen, into a hierarchy of local realisations, starting from massive particles in the form of dynamically multivalued quantum-beat processes forming the observed tangible *matter*. The quantum-beat process constituting each massive, matter-forming particle produces (propagating) deformations in the surrounding material of each protofield that influence its properties and naturally give rise to (maximum) *m×n long-range fundamental interaction forces* of n kinds between field–particles (where each kind is transmitted through its 'native' protofield). For our two protofields with a single coupling, we obtain two (actually observed) long-range interactions different in kind, the electromagnetic (e/m) and gravitational ones, which explain both their real origin and the protofield names, number and roles.

We shall also have *n short-range fundamental interaction forces* originating in direct interaction between (usually unresolved) elementary protofield constituents. Indeed, we observe exactly two short-range interaction forces for our universe ($n = 2$), where the 'weak' force is naturally attributed to the direct interaction between the e/m protofield constituents (thus including a physically real explanation for the standard formal 'electroweak symmetry', now causally 'broken' from the outset), while the 'strong' force is due to the direct interaction between the gravitational protofield elements (thus providing an interesting new relation between gravitational and strong interactions yet to be confirmed). Moreover, since strong interaction occurs between practically unresolved quarks, it follows that our gravitational protofield can be described as a dense quark condensate (where a 'quark' can actually be represented by an ephemeral and quickly changing quantum-beat mode of a deeper complexity sublevel). This conclusion is independently confirmed by recent high-energy nuclei collision experiments [45], where the expected 'quark–gluon plasma' behaved as a dense liquid rather than 'gas' from the Standard Model related to its interpretation of quark confinement (the latter also acquires a new, physically real and consistent explanation in our picture). One can add that real world structures are certainly asymmetrically 'displaced' towards much lighter and more deformable/elastic e/m protofield, which explains world essentially electromagnetic dynamics and contributes to relative weakness of gravitational interactions (see also below).

It is important that thus causally obtained fundamental interaction forces with correct properties emerge in their *naturally quantised and dynamically unified* version [9, 11, 12, 16–19, 23], both due to their common quantum-beat origin. All four fundamental forces are dynam-

ically unified in the quantum-beat process (especially its maximum squeeze state of virtual soliton for more massive, hadronic species); while their internally discrete, quantum structure is due to quantum-beat cycles. In the case of e/m interaction, this quantum structure is realised as exchange of physically real (rather than 'virtual') photons, the latter being small enough, quasi-linear and therefore massless e/m protofield wave-like deformations. Note that such physically transparent photon origin in our description, as opposed to the abstract 'gauge symmetry' of the Standard Model that must then be 'spontaneously' broken by the artificially inserted Higgs field, confirms self-consistently the redundant and contradictory nature of the latter due exclusively to speciality of purely abstract approach of usual field theory, with its simplified 'fundamental' but actually non-existent 'symmetries'. In the case of gravitational interactions, the high density and strong interactions in the gravitational protofield can hardly permit for any real 'graviton' propagation, so that interaction is practically transmitted by quantised density modulations quickly losing their individuality with distance. It is evident also that both e/m and gravitational interactions naturally obey the inverse square law of distance dependence, simply due to the number three of spatial dimensions (now causally explained).

The obtained causally defined and internally unified connection between the numbers of (assumed) fundamental entities (like our protofields), emerging space dimensions and fundamental interaction forces implies that any additional entity, like the omnipresent Higgs field should give rise to more forces and dimensions, in contradiction with observations totally confirming our minimal number of fundamental entities (item (9) in sec. 2). One could speculate that the Higgs field may actually play the role of protofield coupling in our picture, but such vision contradicts both protofield coupling origin (being rather due to separation of previously unified entities) and properties of the Higgs field already possessing massive quanta, interacting with other particles, *etc.* Any additional entity would be definitely redundant at this stage and could be added only in the case of necessity, in order to explain basic properties not accounted for in the present description (now absent).

It is especially important that the proposed concept of complex-dynamical mass emerging in the system of two interacting protofields includes naturally unified (or 'equivalent') inertial and gravitational aspects of mass, thus avoiding this heavy deficiency of the Higgs model (item (10) in sec. 2). According to the above general picture, gravitational interaction between particles (and macroscopic bodies) occurs through the gravitational protofield deformed by respective quantum-beat processes and it is naturally proportional to the quantum-beat rate or (relativistic) inertial mass. Gravitational protofield density de-

termining local quantum-beat frequency becomes inhomogeneous in the presence of massive bodies (other quantum-beat processes), so that instead of Eq. (14′) one gets:

$$M(x)c^2 = h\nu(x) = mc^2\sqrt{g_{00}(x)}\,. \qquad (26)$$

Here, $\nu(x)$ is the local quantum-beat frequency of a test particle, $M(x)$—its total mass, m—its relativistic mass in the absence of gravitational field; conventional 'metric' $g_{00}(x) < 1$ actually describes local gravitational protofield density. In weak fields, $g_{00}(x) = 1 + 2\varphi_g(x)/c^2$, where the gravitational field potential $\varphi_g(x) < 0$ [46]. Since $\nu(x)$ determines the local rate of our causally specified time, one obtains the physical origin of (causal) time retardation effect in gravitational field [9, 11, 12, 16–18, 23], instead of formal postulates about 'deformed' geometric 'mixture' of abstract space and time variables.

In summary, our complex-dynamic mass concept includes not only special-relativistic and gravitational but also general-relativistic effects, now in their causal and *naturally quantised* version. The *equivalence* between inertial and gravitational mass properties is an integral part of this complex quantum-beat dynamics. This is the degree of unification going very far beyond the limits of the Standard-Model scheme (sec. 2). Note that this complex-dynamic quantisation of gravity in our description does not need introduction of yet another additional field of 'gravitons' and related too complicated constructions of usual theory, whereas real gravitons, similar to conventional gravitational waves in the opposite limit, may actually not exist as such within the gravitational protofield due to high dissipativity of its dense quark condensate (see above), contrary to their photonic analogues in the light and elastic e/m protofield.

The same complex-dynamic construction of two interacting protofields, giving rise to the observed variety of massive field–particles and their now unified interaction forces, provides a natural explanation for major features of observed particle species spectrum (thus solving the problem of item (11) from sec. 2), including the notorious 'hierarchy problem' limiting the heaviest observed particles (within their quite sufficient variety) to the electroweak energy scale of 100 GeV, with the conventional Planck mass–energy unit exceeding this quantity by 17 orders of magnitude. In our complex-dynamic mass interpretation, it becomes evident [9, 12, 16, 18, 23] that this huge difference between Planck units and the ultimate observed values of particle properties comes from the incorrect use of the *long-range* (Newton's) gravitational interaction constant γ in the formal dimensional Planck's formulas for particle parameters describing actually the *short-range* state of virtual soliton, *i.e.* the corpuscular state of maximum quantum-beat squeeze of the coupled protofields. That usual, long-range gravitational constant γ

actually accounts for a qualitatively very 'long' and indirect way of gravitational interaction transmission from the e/m protofield perturbation by quantum-beat processes of a gravitational interaction participant to respective local changes of the gravitational protofield matrix, then through gravitational protofield towards the location of another gravitational interaction partner and then back from gravitational to e/m protofield. All those links are effectively weak by their 'induced' and 'media-transmission' character (as well as due to the above world 'displacement' from effectively hidden and only weakly connected gravitational protofield towards the directly observed e/m protofield interface), which also accounts for the well-known weakness of gravitational interaction with respect to e/m interaction (being thus another qualitative confirmation of our picture). By contrast, short-range interaction processes accounting for the heaviest virtual soliton formation involve practically direct protofield (self-)interactions, where the long-range and weak-interaction γ value should be replaced by the effective short-range and strong-interaction value $\gamma_0 >> \gamma$, which can be derived just from the huge difference between the really observed ($m_{\exp}c^2 \cong 10^2$ GeV) and traditional ($m_P c^2 \cong 10^{19}$ GeV) Planck mass values, $\gamma_0 = (m_P / m_{\exp})^2 \gamma \cong 10^{34}\gamma$.

All the really observed extreme values of particle mass and other parameters obtain thus a causal and realistic explanation, without redundant species or 'hidden dimensions' [47, 48] and in agreement with the evident sufficiency of the observed particle spectrum [9, 12, 16, 18, 23]. Actually meaningless traditional values of Planck units should thus be excluded from various other fundamental considerations of usual theory (*e.g.*, in cosmology or quantum gravity), implying their essential modification. Another independent confirmation of the real Planck mass–energy value of the order of 100 GeV (determining the maximum amplitude of non-destructive protofield interaction) comes from its proximity to the heaviest (meta)stable nuclei mass, since an atomic nucleus, with strong interaction between its components, can be considered as complex-dynamic quark agglomerate similar to a hadronic elementary particle. The mass of any such compact hadronic object (be it an elementary particle or a nucleus) greater than $m_{\exp}$ would involve local protofield interaction magnitude greater than the binding energy of the e/m protofield elements, just providing the causal interpretation of the (electro)weak scale, $m_{\exp}c^2 \cong 10^2$ GeV.

In addition to mass, *other intrinsic properties* of elementary particles find their causally complete explanations within the *same* picture of complex-dynamic particle structure [9–23]. Thus, the *electric charge* is but another measure of the same quantum-beat complexity, in agreement with the standard connection between the elementary charge e and the Planck constant h (now understood as the quantum of action complexity; see above): $e^2 = \alpha c\hbar$ (where α is the fine-structure

constant and $\hbar = h/(2\pi)$). It explains the *universal (dynamic) quantisation* of electric charge similar to that of action complexity, but emphasizes the e/m interaction properties of elementary quantum-beat processes. Universal time flow implies *phase synchronisation* of all elementary quantum-beat processes *up to phase reversal*, which explains the existence of *two and only two* opposite kinds of electric charge (corresponding to opposite-phase quantum-beat processes), with their known interaction properties [9, 11, 12, 16–18, 23].

The next major intrinsic property, elementary particle *spin*, also emerges dynamically as inevitable, here highly nonlinear vorticity of the e/m protofield dynamically squeezed towards its corpuscular, virtual-soliton state [9, 11, 12, 16–18, 23]. Because of the protofield shear instability, such highly uneven squeeze cannot practically occur along straight lines and will give rise to protofield curling, spiral motion around each reduction centre. The quantum-beat rest energy, Eq. (15), can now be presented in another form reflecting this internal spin dynamics: $E_0 = h\nu_0 = \hbar\omega_0 = h\nu_0/2 + s\omega_0$, where $\omega_0 = 2\pi\nu_0$ is the quantum-beat circular frequency and $s = \hbar/2$ is the elementary spin angular momentum (for the simplest fermion case). The summands in this expression, $h\nu_0/2$ and $s\omega_0$, can be considered as quantum-beat energy parts due to its 'oscillatory' and 'spinning' components. In addition to the spin origin and key value, we obtain here the causal origin of *magnetic field* (from the extended phase of the same vorticity) in agreement with the laws of electrodynamics [9].

Another important connection of the obtained complex-dynamic mass origin emerges as additional, causal interpretation of the fine-structure and Planck's constants, if we rewrite the mentioned standard relation between e, α and h in a new form:

$$E_e = m_e c^2 = \frac{2\pi}{\alpha}\frac{e^2}{\lambda_C} = N^e_{\Re}\frac{e^2}{\lambda\!\!\!^{-}_C}, \quad \lambda_C = \frac{h}{m_e c}, \quad N^e_{\Re} = \frac{1}{\alpha}, \quad \lambda\!\!\!^{-}_C = \frac{\lambda_C}{2\pi}, \quad (27)$$

where m_e is the electron rest mass and λ_C the Compton wavelength (see Eq. (21′)). It means that $N^e_{\Re} = 1/\alpha$ ($= 137$) can be interpreted as the *electron realisation number* and $\lambda\!\!\!^{-}_C = \lambda_C/(2\pi)$ ($\cong 3.9 \cdot 10^{-11}$ cm) as the *length of elementary jump* between electron realisations (both up to a numerical factor of the order of π) [9, 11, 16, 18, 19, 23], the latter in agreement with a previous interpretation of Eqs. (21), (21′). According to the universal interpretation of this jump length (see above, before Eq. (11)), the Compton wavelength corresponds to the emerging elementary length of this complexity level, $\lambda = \Delta x_r = \Delta_r \eta^r_i$. Note also the remarkable coincidence between thus interpreted *fine-structure constant* $\alpha = 1/N^e_{\Re}$ and *electron realisation probability* α_r defined according to our universal dynamic probability expression of Eq. (7).

Further insight into the complex-dynamic origin of fundamental

constants is obtained from yet another form of the same e–$\hbar$ relation:

$$\hbar = N^e_{\Re}\frac{e^2}{c} = \lambda\!\!\!^{-}_C p_e\,,\ \ \lambda\!\!\!^{-}_C = N^e_{\Re} r_e\,, \tag{28}$$

where $p_e = m_e c = E_e/c$ and $r_e = e^2/(m_e c^2)$ ($\cong 2.8\cdot 10^{-13}$ cm) is the usual 'classical radius' of the electron. As each particle quantum-beat process is a realisation of the protofield interaction EP (Eqs. (4), (5)), the first equation (28) shows that $N^e_{\Re}$ or $\lambda\!\!\!^{-}_C$ can be interpreted as this EP width, e^2/c or p_0—its respective depth, and $\hbar$—its 'volume'. While EP width and depth are different for different particle species, their product, or volume of EP well, is a universal quantity characterising the balance between protofield interaction strength and their deformation properties (expressed, not accidentally, in terms of action-complexity). It provides the ultimate causal origin of the Planck constant $\hbar$ and its absolute universality at the lowest complexity sublevels, including various particle agglomerates such as nuclei [16, 18, 19, 23]. Large-width and small-depth EP realisations, like the one for the electron of Eqs. (28), correspond to light-mass, leptonic particles with $N^e_{\Re} >> 1$ and $\alpha_r, \alpha << 1$ (for respective interaction constant). In the opposite limit, the ultimately deep and narrow EP realisations, with $N^e_{\Re}, \alpha_r \sim 1$, correspond to the heaviest hadronic species or agglomerates.

The second Eq. (28) shows also that the electron EP width $\lambda\!\!\!^{-}_C$ contains $N^e_{\Re}$ sizes of r_e, meaning that each corpuscular realisation of virtual soliton for the electron has the size of r_e, so that the complete realisation set densely fills in the accessible EP width. According to the above general interpretation, this is the size of the emerging space point $r_0 = \Delta x_i = \Delta_i \eta_i^r$ thus equal to the classical electron radius (up to a coefficient close to π) and providing its new, deeper meaning [16, 18, 19, 23].

We thus obtain a whole unified and causally complete picture of particle properties around this complex-dynamic mass interpretation, including the origin, structure and spectrum of elementary particles, their intrinsic and dynamic properties unifying quantum and relativistic behaviour as manifestations of the same complex-dynamic interaction, dynamically unified interaction forces and transparent dynamic interpretation of fundamental constants c, h, α, e and γ, resolving numerous stagnating mysteries and contradictions of usual theory, without artificial introduction of abstract and actually redundant entities, such as additional fields, hidden dimensions and dark matter (see also [9–23] for more details, including causally complete interpretation of *all* quantum and relativistic phenomena, genuine quantum chaos, quantum measurement, transition to classicality, *etc.*). This unified complex-dynamic interpretation includes also *complex-dynamic (dynamically multivalued) cosmology* with dynamically self-adjusted parameters naturally avoiding or solving respective problems

of usual, dynamically single-valued, zero-complexity models, including dark matter and energy being but artefacts of this unitary theory due to its artificial limitations [18, 19] (cf. to item (12) in sec. 2).

The obtained ultimately large spectrum of mutually related problem solutions provides a rarely strong support for the entire underlying picture of unreduced, complex interaction dynamics and its purely dynamic mass concept, including the above *unified causal solution to problems* (1)–(12) (sec. 2) of the Standard-Model, Higgs and other schemes of mechanistic mass generation. Further development and complication of this simplest world interaction configuration (*e.g.*, by additional interaction partners) is not excluded, of course, but should be performed, as follows from the above analysis, only as far as the extremely rich possibilities of this initially simple but unreduced complex-dynamic interaction will appear provably insufficient for explanation of the observed properties.

Let us finally emphasize that such *essential extension* beyond the limits of usual theory towards the causally complete understanding of the universal origin of mass–energy, matter and elementary particles is possible only due to *qualitatively new mathematics* based on *dynamic multivaluedness* of unreduced, *causally complete solution* to any real (many-body interaction) problem [9, 18, 40–42], contrary to always dynamically single-valued (unitary) framework of usual theory replacing the real problem solution with a perturbative or 'exact' (and thus illusively 'unique') solution to another, abstract problem of ultimately reduced dimensionality (including recent imitations of causality in fundamental physics; see [23] for references). As this dynamic multivaluedness of all real systems and objects (starting already from the elementary particles) gives rise to the provably universal concept of complexity and chaos/emergence, one can call this new, realistic mathematical framework (genuine) *mathematics of complexity and emergence* (to be distinguished from numerous dynamically single-valued imitations of complexity and its usual mathematical description without true, qualitative novelty). This unreduced mathematics of complexity provides the *truly* rigorous (because of solution completeness) and naturally *unified* extension of *all* (correct) structures, laws and principles, reducing them to only *one, unified structure* of world dynamics in the form of generalised, *dynamically probabilistic fractal* obeying the unique, *unified law* of the *universal symmetry, or conservation and transformation of (unreduced dynamic) complexity* [9, 18, 19, 22, 23, 40–42, 49]. This omnipresent and permanently probabilistically changing world fractal takes the entire variety of real object forms, while the universal symmetry of complexity remains *always exact* and never broken, but relates irreducibly irregular configurations of observed objects (interaction results), contrary to any usual, unitary symmetry dealing with regular links of regular objects and be-

coming always broken because of this artificial regularity (inevitable in the dynamically single-valued underlying framework).

It is important to see this essential mathematical extension behind the obtained progress in physical properties explanation. Its power is confirmed not only by the emerging causally complete fundamental physics, but also by further applications to higher complexity levels, up to conscious brain dynamics and sustainable development transition [40–42], without any rupture or loss of rigour and completeness in description of any higher-level phenomena usually only externally described in the humanities. Our dynamically multivalued, self-developing process of two starting protofield interaction provides thus the ultimately complete and well-specified answer to the question 'what is reality?' increasingly emerging in fundamental science papers and discussions (without consistent answer within the unitary science framework).

4. WHAT DO THEY REALLY PROBE AT THOSE HUGE EXPERIMENTAL FACILITIES?

Referring to the results of the previous section demonstrating the causally complete complex-dynamic solution to intrinsic problems of the Higgs and other Standard-Model mechanisms of mass generation (sec. 2), we can state that the last LHC experiments as if showing 'convincing signs of the Higgs boson' [1, 2] in reality probe and measure various manifestations of the underlying complex (dynamically multivalued) quantum-beat dynamics within the elementary particles and in their interaction in emerging agglomerates (sec. 3), in this case at the highest values of protofield interaction magnitude [23]. The observed features of the collision product spectra [1, 2] should therefore be interpreted not as signs of new physical entities (Higgs field and bosons) existence, but as results of resonances in those complicated (strong) interaction processes between high-energy collision products, where the probed ultimately high protofield coupling energy (of the order of $m_{\mathrm{exp}}c^2 \cong 10^2$ GeV) could be a general reason for resonant behaviour. At least, some of these resonances could well result just from those product interaction processes (such as 'gluon fusion') that would give rise to the Higgs boson emergence according to the accepted Standard-Model analysis, but actually without any such qualitatively new entity existence, the latter being replaced by generally quite ephemeral but sometimes perceptible resonances between those interacting collision products. We thus get rid of an entire redundant, purely abstract entity, the Higgs field (remaining unnecessary beyond Standard-Model limitations eventually due to its unitary reduction scheme; see the end of sec. 3) and the related heavy, fundamental and stagnating problems (items (1)–(12) in sec. 2). We obtain instead the totally universal, con-

sistent and realistic (causally complete) complex-dynamic interpretation of the origin of mass intrinsically unified with solution of all other mystified problems of unitary fundamental physics (sec. 3) and actually completing the basic ideas put forward and strongly defended by Louis de Broglie [26–39], one of the founding fathers of the new physics [37].

Whereas complicated features of those collision-product resonances would certainly need more detailed analysis (now within the above new vision), a general confirmation of the proposed parsimonious interpretation comes from a variety of other, smaller features seen, *e.g.*, in the emerging photon spectra (like in Fig. 3 in [2]) that should account for other occurring resonances apparently not related to Higgs boson decomposition. The entire picture of this new, much more consistent interpretation becomes qualitatively shifted towards a multitude of generally occasional interaction processes showing a complicated 'portrait' of complex many-body interactions involved and not revealing the 'spectacular' but illusive existence of a new physical entity (now seen as truly redundant and inconsistent in its supposed role and connections; see sec. 2). And although the seducing ambition of a 'great discovery' seems to be lost in this Higgs-free interpretation, it actually contains something much more important, the unified solution not only to the mass origin problem, but to practically all stagnating problems and difficulties of fundamental physics, simultaneously opening quite new perspectives for its further development [16, 23], otherwise seriously compromised today [9, 22, 50–55].

In particular, as a result of this new interpretation in terms of dynamically multivalued interaction dynamics, one can see the emerging qualitatively new strategy and perspective of accelerator and other big-scale research in experimental fundamental physics. Since particle species mass spectrum is now basically limited, as we have seen above (sec. 3), to already observed mass values of the order of 100 GeV, being the physically real, now consistently explained value of the Planck mass unit (replacing the unrealistically high and incorrect conventional value), there is no need to randomly and uselessly hunt for other, ever higher-mass species that are not only redundant for the known world structure (the fact evident already empirically), but provably cannot exist in the self-consistent universe dynamics (together with ever heavier atomic nuclei exceeding their known largest masses of the same order of magnitude). One also gets rid of so many useless but otherwise persisting, ever more numerous entities arbitrarily 'assumed' within the deficient unitary models, such as 'supersymmetry' or various 'brane worlds' and 'dark matter' species, however, without bringing any true consistency and now becoming provably unnecessary. By contrast, instead of this purely empirical and thus basically blind, but quite expensive and therefore ultimately inefficient (if not potentially

dangerous) search, one can now concentrate on a much more reasonable, causally substantiated detailed study of already attained, quite accessible energy scales with potentially important applications (*e.g.*, new energy sources) acquiring their *qualitatively new perspectives* just due to that internal complex (multivalued) interaction dynamics within the particles and their agglomerates.

In that sense, one gets here another, *more general and eventually much more important answer* to the main question of this paper: they also probe the fundamental limits of the entire standard theory and approach at LHC and other huge experimental facilities, with *now* emerging important and consistently specified (above) conclusions about the necessary changes in both theory and experimental strategy. It involves not only LHC but all other huge facilities, including those used in cosmological studies, space telescopes, *etc.* From that point of view, one deals not with a disappointing or indefinite result, but with a large window of qualitatively new opportunities for the entire fundamental physics (otherwise stagnating in an unpleasant impasse), where 'negative' results with respect to various abstract but now definitely illusive entities are very comfortably compensated by that new, qualitatively extended and causally complete outlook pointing to various practically important discoveries without huge new investments (in the time of lasting crisis!), but with reasonably expected high output. The unavoidable 'payment' for that huge efficiency growth comes in the form of the necessary extension from dynamically single-valued world projection (of entire usual framework, including its imitations of 'complexity', 'self-organisation' and 'chaos' [9, 22, 23, 50]) to the unreduced, multivalued and much richer picture of its real dynamics (already largely outlined in the presented approach [9–23, 40–42, 49, 50]), but that 'additional work' will itself appear rather as a gift, ensuring much deeper (eventually provably complete), more interesting and practically rewarding insight into the nature of reality.

This future work may certainly involve more detailed description of the fundamental protofield interaction process and its higher sublevels. In this paper, we only summarised basic results of unreduced many-body interaction analysis [9–23], already demonstrating its qualitatively higher efficiency for particular fundamental (new and old) problem solution. This unified solution is strongly supported by a large variety of experimental observations, from special experimental detection of quantum-beat pulsation, to qualitative results of recent quark-gluon plasma experiments and solution of numerous stagnating contradictions and 'mysteries' of the (old) new physics (see, *e.g.*, papers [14, 16, 18, 23] for extensive lists of major confirmation points). It seems therefore that there was no sense at this stage to pass immediately to special models of interaction processes and entities residing largely beyond (or right on the border of) accessibility by experimental

facilities of this world just fundamentally emerging as higher interaction complexity levels. However, such more detailed analysis can be expected as a part of further work within this qualitatively new fundamental research strategy.

5. FURTHER SCIENCE PROGRESS: TO BE OR NOT TO BE?

Finally, yet higher level of the *answer to the main question* of this paper involves the structure and operation mode of fundamental science as a whole, because those ultimately complicated and resource-consuming, potentially critically important fundamental research efforts certainly probe the efficiency and perspectives of modern science as a major human enterprise on the scale of entire planetary civilisation development, the latter strongly asking for qualitatively new advances right now, at this moment of critically stagnating results of spectacular previous progress. Moreover, that probing of the overall science efficiency provides ever more definite and unfortunately disappointing conclusions revealing, like especially in the case of recent LHC activity, a strangely low creativity in the theoretical, conceptual part, accompanied by disproportionally loud glorification of 'our science', the best in the universe (or rather the only one we know), and ever greater indifference of society remaining however the only source and the ultimate purpose of scientific endeavour.

Returning to the results of different LHC experiment interpretations and their comparison elucidated in this paper, one could ask, just for one example, why the striking difference between 'usual' and our complex-dynamic mass (and other properties) interpretations lacks any reference in wider professional and popular science literature and discussion, despite being clearly presented in quite accessible sources already for a long enough time (at least, since 1997–1998) and despite strong and practically important advantages provided by our explicitly extended analysis results. The answer will be delusively simple and similar to that for any other 'alternative' explanation effort, actually ever since original de Broglie's studies back in 1923–1924 [13–15, 36, 37]. The problem is that in the current system of research organisation and practice, there is only one approach and group of interpretations, which is accepted for comparison with even very expensive and effort-consuming experiments, for years and decades, irrespective of its efficiency and results. It means that whatever the results of that probing (on the whole quite efficient as such!) by those huge facilities of the state and practice of fundamental science, nothing will change in the ongoing research, intentionally liberated from any real alternative, both at the professional and public levels. Therefore, today fundamental science is the only field of human activity where, contrary to its unique and now critically high importance for the entire human civili-

sation development, a single interpretation or approach is most often accepted for competition on purely subjective grounds, even when it not only lacks visible advantages over other really existing approaches (though such advantages are generally asserted, without comparison!), but actually represents close to the worst possible choice for interpretation of extremely difficult and professionally highly elaborated experimental work. In our case, we have even a rigorous expression of such situation, since the conventional, 'dynamically single-valued' projection of the real, 'dynamically multivalued' interaction dynamics evidently represents the strongest, most incorrect possible reduction of reality (from extremely many system realisations to only one, 'average' realisation) [9, 18, 19, 22, 50].

However, there is time for everything, and now this increasingly alarming test of the real state of science by LHC and other huge facilities, showing critically low efficiency due to practical and thoroughly maintained absence of free, creative competition of professional scientific ideas, cries out for the necessity of definite change in a well-specified direction of multiple (and different) interpretations practically participating in experimental result analysis, with respective attention and resources allocated, at least, in approximate proportion to those interpretations efficiency (cf. sections 2–4). One can say that we are living now a 'super-critical' phase of famous 'paradigm change' process [56], which, due to accumulating severe problems in science and society, even exceeds the entire concept of those conventional 'scientific revolutions'. Taking into account today speed of development and 'distributed criticality' omnipresent in practically all aspects of life and human activity, it become evident that starting from now this highly technically, empirically developed civilisation cannot permit itself any more to remain within those traditional long periods of stagnation followed by unpredictable 'revolutions': the next revolution may actually come too late to have any importance at the level of a totally corrupt science system and inevitably destroyed civilisation. In reality, one doesn't need to start with any revolution, but simply to accept more than one (essentially different) approach in interpretation of extremely important and resource-consuming experiments (giving otherwise strongly incomplete results, without real progress). The balance between the expected outcome and the necessary change is definitely in favour of the former, and it can only increase.

These necessary changes in science organisation and practice, thus constantly probed and clearly detected by huge facilities and their experiments interpretation, do have however a much more extended and this time indeed qualitatively big realisation in the form of the 'last scientific revolution' [50], after which one doesn't need any more to make special efforts to 'liberate research creativity', as this one will be permanently ensured by the qualitatively new science system. It is in-

teresting that organisation and dynamics of the latter, as well as the transition to this new system from the current degrading unitary science organisation, can be objectively specified within the same universal complexity concept that underlies consistent mass interpretation defended in this paper. Keeping in mind that additional and not accidental correlation, one can start with a reasonable and feasible application of dynamic complexity ideas to LHC and other fundamental experiment interpretation as demonstrated in this paper, thus suitably developing, just at the right moment, the old and wrongfully forgotten ideas of Louis de Broglie and other realistically thinking fathers of the new physics.

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