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Logic of Nature Seen in Particle Properties, in the Rise of the Universe and Consequences for the Structure of Complex Systems

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ABSTRACT

To push realistic learning processes and simulations to extremes far beyond present artificial intelligence, they must be conform with nature and have to follow mathematical logic. To see in full strength the logic structure of nature, the study of basic systems - as hadrons and leptons - is best suited, because ambiguities due a large complexity are reduced to a minimum.

To describe such systems, a new quantum theory has been derived recently, in which in addition to the usual treatment of fermions bosons are considered also to fulfill energy and momentum conservation explicitly. With negative binding energies of fermions and positive ones of bosons, the total energy is zero, giving rise to a quantitative description of hadron and lepton properties with uncertainties < 1/1000.

In addition, this formalism provides a mechanism, by which particles could be created out of the vacuum, indicating that the universe emerged out of nothing (the vacuum). This leads finally to a realistic view of the cosmic evolution.

Further, the present theory can be taken as basis for the description of complex systems in gravity, heavy atoms, molecules, materials and even biological structures.

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Introduction

Scientific descriptions should be always based on correct mathematical logic (as defined e.g. by Aristoteles or in modern theories). If one wants to go beyond present-day artificial intelligence, as e.g. in simulations of physics or other branches of nature to extreme temperature, pressure or complexity, one should make sure that all known conservation laws of physics are satisfied. However, it is important to test also, whether this is conform with the real development of nature. For complex systems this is difficult because of their high complexity. Therefore, such stringent tests can be made only for basic systems, as particles in form of hadrons and leptons.

During the last century enormous progress has been made in the understanding of fundamental physics. With the discovery of atoms, hadrons and leptons we have learnt that the physics of microscopic systems is different in principle from that of macroscopic subjects and has to be described by quantum mechanics. Present research in particle physics is focussed on large accelerator experiments to search for new particles, supersymmetric particles, magnetic monopoles, axions and other exotics, which have been predicted in extensions of the Standard Model of particle physics [1]. This theoretical framework contains effective theories of electromagnetic, strong and weak interactions with 20-30 parameters, which had to be adjusted to experimental data. However, in this model the internal structure of particles cannot be understood. One needs clearly more basic theoretical descriptions, in which the number of parameters can be reduced by basic physical conservation laws, as energy and momentum conservation. Further, these theories should also respect causality and relativity.

If we talk of a logic and causal development of nature, we have still a serious problem with the understanding of the evolution of the universe. In Einstein's theory of the universe and current cosmological models the universe evolves out of the Big Bang - what happened before is outside the scope of these theories. This may be the reason, why in cosmological models dark forms of matter and energy are needed, which could never be clearly observed. According to these models only about 4 % of the visible matter of the universe should be due to real particles in form of galaxies, stars and gaseous nebulae or dust, but the predicted dark matter could never be detected, even not with the new *James Webb* space telescope, which is able to look with highest resolution far into the past of the universe.

There are other observables, as the broken matter-antimatter symmetry (in the universe very little antimatter has been observed) or the fact that the expansion of the universe is accelerating [2]. It seems that these puzzles can be explained only, if the history of the universe before the Big Bang is taken into account [3].

Here it should also be mentioned that a satisfactory theory of gravitation does not exist, which goes beyond those of Newton and Einstein. High dimensional string or string-like quantum theories have been proposed for the description of gravity. However, they need hundreds of parameters, impossible to adjust in a reasonable way [4].

Because of these problems and the fact that the universe is made of particles, it is of crucial importance to find a common theory of fundamental systems for the description of particle properties and of the development of the universe.

What Is the Required Structure of Such a Fundamental Theory?

The only realistic scenario of the rise of the universe is that it emerged out of nothing (the vacuum). This is possible only, if particles could be formed with a total energy equal to zero. To fulfill this requirement, they should consist of two different elementary ingredients, fermions, which we can observe (with charge and spin 1/2), and bosons (without charge and spin 1). This is different from the current view of particles as bound states of fermions only. These extra bosons can be considered as photons, which are bound and therefore cannot be observed directly. Because the vacuum has no charge, only fermion-antifermion pairs can be created, which feel an attractive interaction, whereas the interaction between bosons is repulsive. This is exactly the property of the electromagnetic interaction, which is described by the theory of *electrodynamics*, see e.g. ref. [5].

Further, we should make sure that such a theory respects all basic conservation laws of physics, as conservation of energy and momentum. Energy conservation is fulfilled by the above requirement that the total energy E_{tot} is given by the sum of fermion and boson energies $E_{tot} = E_{ferm} + E_{bos}$, where E_{ferm} and E_{bos} are the fermion and boson (binding) energies. Momentum conservation requires that the average momenta of fermions ($\tilde{q}_{ferm}$) compensate those of bosons ($\tilde{q}_{bos}$).

From these requirements we can construct directly the form of the interacting Lagrangian L_{int} (this describes the complete dynamics of a bound state in a Lorentz invariant form, see e.g. ref. [5]).This function has two parts, fermion fields $\bar{\Psi}$, Ψ and boson fields A_ν, A^ν, the latter contained in covariant derivatives D_ν, D^ν on the left and right; further a bosonic (electromagnetic) interaction D^μ, which acts between fermions and between bosons

$$L_{int} \sim (\bar{\Psi}\, D_\nu)\, D^\mu\, (D^\nu\, \Psi)\,. \qquad (1)$$

The covariant derivatives D_μ and D_ν contain in addition to boson fields the derivatives of the fermion fields. Because of the fermion-boson symmetry in eq. (1), the probabilities in space (or wave functions) of fermions and bosons are of similar exponential form for different bound states; therefore, hadrons and leptons can be described in a similar way. Even atomic bound states and gravity can be described in this formalism, in which atoms are described by protons and electrons bound electrically and gravitational bound states by magnetic binding of hydrogen atoms.

In addition, binding energies deduced from this Lagrangian need only three or four parameters, which are completely determined by the conservation of energy and momentum. This is the only existing theory *based on first principles*, which means that no free adjustable parameters are present and absolute results are obtained. Apart from the dynamics of the bound state, the formalism contains three potentials, two binding potentials of fermions and of bosons and the “confinement” potential. This dynamical potential is of crucial importance for self-generation of particles out of the vacuum: During overlap of fluctuating bosons, fermion-antifermion pairs can be created and then bound by a boson-exchange potential [3, 6]. Another important ingredient of the theory is the existence of second-order or acceleration terms, which can lead to a compression of complex bound states [3].

Internal Structure of Particles

By applying the above formalism, a quantitative description of the properties of simple mesons, as ω(0.78 GeV), Φ(1.02 GeV) or J/ψ(3.98 GeV) is obtained, but also of all three leptons, *electron*, μ- and τ *-leptons*, including their magnetic dipole moments and rotation frequencies within errors of < 1/1000 [6].

Interesting is further that all particles or complex systems contain exactly the same coupling to the vacuum (with a total energy equal to zero), a *fingerprint of genesis*, the initial creation of the universe out of the vacuum - whereas astrophysical observations are limited to the development of the universe after the Big Bang.

Present View of the Evolution of the Universe

After the beginning of space-time particles could emerge out of the vacuum of fluctuating boson fields and massless fermion-antifermion pairs. During overlap of these boson fields fermion-antifermion pairs could be created, then confined and bound to form simple hadrons and lepton-antilepton (as electron-positron) pairs, as described above. Over almost eternal times a huge system of a tremendously large number of particles could be accumulated, which decayed eventually to proton-electron and antiproton-positron pairs, which interacted mainly by gravity. By instabilities due to tiny charge-parity breaking processes, the proton-electron pairs started to separate from the antiproton-positron pairs and were driven to a collapse [7]. This led to the Big Bang, in which a large amount of (proton-electron) matter and the total (antiproton-positron) antimatter annihilated. The remaining matter were heated up violently and bounced back to open space, which gave rise to the present rapidly expanding universe. More details of this process are given in ref. [3].

Description and Simulations of Complex Systems

Because of the very special structure of the theory, the coupling of three-dimensional fermion and two-dimensional boson fields, the wave functions of simple and complex systems have to be similar. This means that this formalism should be applicable also to describe properties of rather complex objects, as galaxies, nuclei, atoms and more complex objects. Concerning gravity, it has been shown that the rotation of galaxies is well described in the present formalism, see ref. [8]. Black holes can be described also, explained by an accelerated compression of the system, followed by violent emission of annihilation photons in the axis of rotation. For other cosmic objects of more or less compact forms (stars and nebulae), an extension of the present framework is possible, but with different components of localised or diffuse structure.

For light atoms the present framework yields a quantitative description, see ref. [9]. For heavier atoms, electron wave function of p, d and f ... structure have to be added. With increasing complexity towards large molecules, complex materials and simple biological structures, the theoretical effort becomes more and more involved.

Of particular future interest is the structure of macro-molecules and cells. For such complex objects the motion, excitation and interference between local structures lead to very complicated features, as observed in reality. Since, however, everything is based on the same fundamental theory, it is not unrealistic to assume that in this framework complex simulations become possible in the future and allow to specify relevant mechanisms, which could lead to important progress in biology and medicine.

Under the internet address https://h2909473.stratoserver.net all calculations on hadrons and leptons can be run on line, where also the underlying fortran source code (written in gfortran) can be inspected.

Conclusion

For the first time an accurate description of particle properties with errors below one part in 1000 is obtained, which yields also a logic, causal and realistic picture of the evolution of the universe. In this new quantum theory the total particle energy is zero, indicating that particles or particle pairs carry the properties of the vacuum, a *fingerprint of genesis*. Based on these results, future simulations of complex systems may become feasible in physics, biology and life sciences.

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