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Review Article

Fingerprint of Genesis in the Structure of Particles

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Abstract

A short review is given on a new quantum theory of particles, in which in addition to the usual treatment of fermions also bosons are used to satisfy energy and momentum conservation. With opposite binding energies of fermions and bosons the total energy is zero, indicating that particles could have been created out of the vacuum. This leads to a quantitative description of particles and provides a realistic view of the early evolution of the universe before the Big Bang.

Keywords: Fundamental Physics; Quantum Theory; Coupling of Particles to the Vacuum

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 principally different from that of macroscopic subjects, because microscopic particles cannot be divided any more and are bound by fundamental forces. For their description classical mechanics did not work any more and required the development of 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 model 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.

This is also important for an understanding of the development of the universe. Present cosmological models are purely phenomenological. They describe only the evolution of the universe after the Big Bang. What happened before is outside the scope of these theories. However, the evolution before the Big Bang may be of crucial importance for an understanding of the broken matter-antimatter symmetry (in the universe very little antimatter has been observed) or the accelerated expansion of the universe [2].

Here it should 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 [3] have been proposed for the description of gravity. However, they need hundreds of parameters, impossible to adjust in a reasonable way.

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 (with charge and spin 1/2) and bosons (without charge and spin 1), a structure 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 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 ref. [4] or other physics text books.

As a second point we should make sure that in such a theory all basic conservation laws of physics are respected, conservation of energy and momentum. The first condition 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. [4]). This function has two parts, fermion fields $\bar{\Psi}$, Ψ and boson fields D_ν, D^ν on the left and right; further a bosonic (electromagnetic) interaction ~ D^μ, which acts between fermions and between bosons

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Because of the fermion-boson symmetric form on the right and left of eq. (1), the spacial distributions (or wave functions) of fermions and bosons are of similar exponential form for different bound states, hadrons and leptons, but also for gravitational systems, as galaxies and the matter distribution of the early universe before the Big Bang.

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 gives rise to the only theory based on first principles. which needs no free adjustable parameters. Apart from the dynamics of the bound state, the formalism contains only three potentials, two binding potentials of fermions and of bosons and the ”confinement” potential, a dynamical potential, in which fermion-antifermion pairs are confined during overlapping bosons. This is of crucial importance [5] for self-generation of particles out of the vacuum. 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.

Internal structure of particles

By applying the formalism described above, a quantitative description of masses and radii of simple mesons is obtained [5], as ω(0.78 GeV), φ(1.02 GeV) or J/ψ(3.98 GeV), but also of all three leptons, electron, μ- and τ -mesons. In addition, for leptons also their magnetic dipole moments and rotation frequency could be determined with high accuracy.

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 the early evolution of the universe out of the vacuum - although 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 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 [6], the proton-electron pairs started to separate from the antiproton-positron pairs and were driven to a collapse. This led to the Big Bang, in which a large amount of matter and the total antimatter annihilated. The remaining matter has been heated violently and pushed to open space, which formed the present rapidly expanding universe. More details of this process are given in ref. [7].

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

From the rigorous requirement of energy and momentum conservation a first quantitative description of particle properties is obtained. Due to a zero total energy, particles or particle pairs carry the properties of the vacuum and thus the fingerprint of genesis.

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