

THE MASS GENERATION MECHANISM AND THE SCALAR BOSON

- The problem of the origin of mass for the elementary constituents of matter such as electrons and quarks (these are called fermions) can be solved by assuming that there is a field pervading space. One may visualize this field as a kind of sea embedding the whole universe. Particles traveling through the “sea” are slowed down and have a velocity smaller than the velocity of light: they become massive. Waves in the “sea” are composed of quantum particles (called bosons): these are the massive scalar bosons, (hopefully?) detected at the LHC, testing the existence of the “sea-field”. The word “scalar” means that the field has no orientation.

- The problem of the origin of mass is related to the problem of the origin of forces acting on these elementary constituents but practically not detectable at macroscopic scales, such as those responsible for the radioactivity of atomic nuclei. To explain this relation, I first sketch the history of physics up to the theory of mass generation by the “sea-field”.

Physics, as we know it, is an attempt to interpret the diverse natural phenomena as particular manifestations of general testable laws. Starting with Galileo and Newton, this enterprise reached impressive developments in the first half of the twentieth century:

a) The Newton law of gravitation (1687), governing the universal attraction of masses, from falling bodies to the motion of celestial objects, was corrected and extended by Einstein to the so called theory of general relativity (1915), which opened to scientific investigation the cosmological expansion of the universe.

b) The Maxwell theory of electromagnetism (1864), governing all electric and magnetic phenomena as well as the propagation of light, was made consistent with the new quantum formulation of physics. This opened the domain of electromagnetism to chemistry and to the whole atomic world.

These developments made it conceivable that all phenomena, from the atomic level to the edge of the visible universe, be governed solely by the known laws of general relativity and quantum electrodynamics, the quantum version of Maxwell’s electromagnetic theory.

- But Gravitational and electromagnetic forces are fundamental **long range forces**, meaning they are felt by objects, no matter how far they are separated from each other. But as I mentioned, there are forces acting on elementary constituents of matter that are felt on such very small distance scales and are negligible at larger distances. In the beginning of the 60s, the theoretical interpretation of such **short range fundamental forces** seemed to pose insuperable obstacles.

- The solution was found in 1964 by Robert Brout and myself. Long range forces are transmitted by waves traveling with the velocity of light and hence are composed of zero mass particles (e.g. the photons). We assumed that all fundamental interactions are transmitted in a similar way by “generalized photons”. We introduced the aforementioned “sea field”. Generalized photons are slowed down and become massive. The forces they transmit can then only reach neighboring objects. In this way, the “sea-field” transmutes long-range forces into short range ones by giving mass to generalized photons.

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For sake of simplicity, the above discussion omits one essential subtle point which I shall now evoke.

When I discussed the massive waves of the “sea-field”, I did not mention that its very existence gives rise also to another type of waves, akin to sound waves, which are not slowed down and hence propagate with the velocity of light. This implies that the “sea-field” carries massless particles (labeled Nambu-Goldstone bosons). Such particles are not observed and hence the mass generation of elementary objects by the “sea-field” appears inconsistent with observation.

*It is the mechanism for generating short range forces by giving mass to generalized photons that saves the day! Photons and “generalized photons” arise from fields (labeled gauge fields) which have a very special property: they have a bolt that obstructs the generation of massive generalized photons. But the massless Nambu-Goldstone bosons break the bolt by being absorbed into the gauge fields. Thus it is the disappearance of massless Nambu-Goldstone bosons which allows for massive generalized photons!!! Thus our mechanism yields not only the generation of short-range fundamental forces but also a **consistent** generation of mass for the elementary objects on which they act.*

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Detailed references can be found in the press release of the ULB.

François Englert