
Noncommutative standard model

The **non-commutative Standard Model** is an extension of the Standard Model to include a modified form of general relativity, developed by Alain Connes using his theory of noncommutative geometry. This unification implies a few constraints on the parameters of the Standard Model. One of the constraints determines the mass of the Higgs boson to be around 170 GeV, comfortably within the range of the Large Hadron Collider. However, a Higgs mass of 170 GeV has been excluded to a confidence level of 95% using data from Tevatron experiments.^[1]

Background

Today it is thought that there are four elementary forces: the gravitational force, the electromagnetic force, the weak force, and the strong force. Gravity has an elegant and experimentally precise theory: Einstein's general relativity. It is based on Riemannian geometry and interprets the gravitational force as curvature of space-time. It has a Lagrangian formulation with only two real parameters, the gravitational constant and the cosmological constant.

The other three forces also have a Lagrangian theory, called the Standard Model. Its underlying idea is that they are mediated by the exchange of spin-one particles, the so-called gauge bosons. The one responsible for electromagnetism is the photon. The weak force has the W and Z bosons, and the strong force is thought to result from gluon exchange. The gauge Lagrangian is much more complicated than the gravitational one: at present, it involves some 30 real parameters. This number may still increase. What is more, the gauge Lagrangian must also contain a spin-zero particle, the 'Higgs boson'. So far this particle has not been observed and if it does not show up at the Large Hadron Collider in Geneva, the consistency of the Standard Model is questionable.

Alain Connes has generalized Bernhard Riemann's geometry to noncommutative geometry. It describes spaces with curvature and uncertainty. Historically, the first example of such a geometry is quantum mechanics, which introduces Heisenberg's uncertainty relation by turning the classical observables of position and momentum into noncommuting operators. Still, noncommutative geometry is close enough to Riemannian geometry that Connes was able to redo general relativity with it. In doing so he obtained the gauge Lagrangian as a companion of the gravitational one, a truly geometric unification of all four forces. Connes has thus provided a totally geometric formulation of the Standard Model where all the parameters are geometric invariants of a noncommutative space. Hence, electron parameters like mass are now analogous to π !

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