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Mass Generation, the Cosmological Constant Problem, Conformal Symmetry, and the Higgs Boson

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Abstract

In 2013 the Nobel Prize in Physics was awarded to Francois Englert and Peter Higgs for their work in 1964 along with the late Robert Brout on the mass generation mechanism (the Higgs mechanism) in local gauge theories. This mechanism requires the existence of a massive scalar particle, the Higgs boson, and in 2012 the Higgs boson was finally discovered at the Large Hadron Collider after being sought for almost half a century. In this article we review the work that led to the discovery of the Higgs boson and discuss its implications. We approach the topic from the perspective of a dynamically generated Higgs boson that is a fermion-antifermion bound state rather than an elementary field that appears in an input Lagrangian. In particular, we emphasize the connection with the Barden-Cooper-Schrieffer theory of superconductivity. We identify the double-well Higgs potential not as a fundamental potential but as a mean-field effective Lagrangian with a dynamical Higgs boson being generated through a residual interaction that accompanies the mean-field Lagrangian. We discuss what we believe to be the key challenge raised by the discovery of the Higgs boson, namely determining whether it is elementary or composite, and through study of a conformal invariant field theory model as realized with critical scaling and anomalous dimensions, suggest that the width of the Higgs boson might serve as a suitable diagnostic for discriminating between an elementary Higgs boson and a composite one. We discuss the implications of Higgs boson mass generation for the cosmological constant problem, as the cosmological constant receives contributions from the very mechanism that generates the Higgs boson mass in the first place. We show that the contribution to the cosmological constant due to a composite Higgs boson is more tractable and under control than the contribution due to an elementary Higgs boson, and is potentially completely under control if there is an underlying conformal symmetry not just in a critical scaling matter sector (which there would have to be if all mass scales are to be dynamical), but equally in the gravity sector to which the matter sector couples.