Gauge-Higgs unification at finite temperature [1]

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Much attention has been paid to the scenario of gauge-Higgs unification for the possibility to solve the gauge hierarchy problem without introducing supersymmetry (SUSY). In the scenario, Higgs fields are regarded as extra components in the original gauge field, and the higher dimensional gauge invariance ensures the Higgs field is strictly massless. If spatial coordinates are compactified, then, the extra component gauge field behaves as the Higgs field at low energies. The Higgs field can develop the vacuum expectation values (VEV) through the dynamics of the Wilson line phases, which is called the Hosotani mechanism. The gauge symmetry can be broken by the VEV, and the Higgs field becomes massive at the quantum level. This is similar to the famous Coleman-Weinberg mechanism.

We study the effect of finite temperature on the gauge-Higgs unification. Namely, from a point of view of the electroweak baryogenesis, we are very much interested in the order of the phase transition at finite temperature because in order for the scenario of the electroweak baryogenesis to work well, one of the famous Sakharov's three conditions, out of equilibrium, that is, the strong first order phase transition must be realized in the theory. This is a very crucial point for the scenario, and it has been well known that the minimal standard model is ruled out because the Higgs mass must be much smaller than the experimental bound in order to satisfy the condition.

In the scenario of the gauge-Higgs unification, we can obtain the strong first order phase transition with the heavy Higgs mass. For the certain (SUSY) gauge model, we have

$$\frac{v(T_c)}{T_c} \simeq \frac{1}{g_4} \times 1.19\ (1.212) > 1 \quad \text{with} \quad m_H \simeq g_4^2 \times 129\ (130) \quad (\text{GeV}),$$

where g_4 is the four dimensional gauge coupling, $g_4 \equiv g/\sqrt{2\pi R} \sim O(1)$.

We find that, like the four dimensional field theory at finite temperature, the boson fields yield the cubic terms with respect to the order parameter in the "high temperature" expansion, $LT > 1$, which is essential for the strong first order phase transition. At the same time, the boson fields in the models also play an important role to enhance the magnitude of the Higgs mass. That is why the heavy Higgs mass and the strong first order phase transition are compatible.

We are discussing the phase transition in more realistic contents and also studying the effect of finite density on the gauge-Higgs unification.

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