and $y_i = 0$ are invariant. For a especial choice

$$K = f(\eta) + \ln[W(\phi)/M_{\rm P}^3]^2 + g(y)\,, \qquad (145)$$

The $N = 1$ SUGRA potential reads [416, 424]

$$V_F = e^{f(\eta)+g(y)}\left[\left(\frac{f'^2}{f''} - 3\right)\frac{|W|^2}{M_{\rm P}^2} - \frac{1}{f'^2}\frac{|W_i|^2}{M_{\rm P}^2} + g_a(g^{-1})^a_b g^b \frac{|W|^2}{M_{\rm P}^2}\right]. \qquad (146)$$

Note that there is no cross term in the potential such as $|\phi_i^* W|^2$. As a consequence any tree level flat direction remains flat even during inflation [416] (in fact it is the Heisenberg symmetry which protects the flat directions from obtaining Hubble induced masses [423]).

A particular choice of Kähler potential, i.e.

$$K = -3\ln(\varphi + \bar{\varphi}),$$

arises quite naturally from string compactifications [425, 426]. For a constant superpotential, W_0, the F-term of the potential yields;

$$V_F = e^{K/M_{\rm P}^2}\left[(K^{-1})^j_i K^i K_j - 3\right]|W_0|^2\,. \qquad (147)$$

and for the above choice of the Kähler potential, $V_F = 0$ for all φ, because the Kähler potential satisfies $(K^{-1})^j_i K^i K_j = 3$, this is a property of no-scale model. The symmetry is broken by gauge interactions or by coupling in the renormalizable part of the Kähler potential. Then the mass of the flat direction condensate arises from the running of the gauge couplings.

F. (SUSY) Grand Unified Theories

The observation that within SUSY the value of three gauge couplings nearly meet at $\sim 2\times 10^{16}$ GeV has led to the idea [37] that the three gauge groups emerge from a single (Grand Unified) group G_{GUT} with a single gauge coupling g_{GUT} [38]. Another motivation for

[37] Initial attempts were made by Pati and Salam [427] in $SU(2)_L \times SU(2)_R \times SU(4)_C$ model, where quarks and leptons are unified-a lepton becomes the fourth color of a quark. Although the model did not have gauge unification, but later models unified the couplings in a left-right symmetric model [350, 428, 429].

[38] The requirement of a simple gauge group can be relaxed. It is also possible to have a single high energy gauge coupling constant with a non-simple gauge group made up of products of identical groups, i.e. $G_{GUT} = H \times H \times \ldots$. The single gauge coupling constant is ensured by imposing an additional symmetry that render the theory invariant under exchange of the factors of H.