where $\Psi = H_u$ *if* $R_\Phi = +1$ and $\Psi = L$ *if* $R_\Phi = -1$. Taking into account of the inflaton superpotential mass term: $(m_\phi/2)\,\Phi\Phi$, and defining $X_{1,2} = (H_u \pm \Psi)/\sqrt{2}$, the *renormalizable part of the potential*, which is relevant for the inflaton decay into MSSM scalars is given by:

$$V \supset \frac{1}{2}m_\phi^2\phi^2 + g^2\phi^2\chi^2 \pm \frac{1}{\sqrt{2}}gm_\phi\phi\chi^2\,, \tag{417}$$

where χ denotes the scalar component of $X_{1,2}$ superfields, and we have only considered the real parts of the inflaton, ϕ, and χ field. Further note that the cubic interaction term appears with different signs for χ_1 and χ_2, but this is irrelevant during inflaton oscillations.

In addition to the terms in Eq. (417), there are also the self- and-cross-couplings,

$$V_D \supset \left(\frac{g^2}{4}\right)\left(\chi_1^2 - \chi_2^2\right)^2 + \alpha\chi_1^2\chi_2^2\,, \tag{418}$$

arising from the superpotential and D-terms respectively (α is a gauge fine structure constant). Therefore even in the simplest SUSY set up the scalar potential is more involved than the non-SUSY case given in Eq. (378), which can alter the picture of preheating presented in the literature, see for the detailed discussion in Refs. [122, 123] [93].

D. MSSM flat directions, reheating and thermalization

The MSSM flat directions have important role to play in SUSY reheating and thermalization [122, 123]. Consider a MSSM flat direction, φ, with the corresponding superfield denoted by φ (only for flat directions we are denoting the superfield and the field with the same notation in this section). Note that since φ and X superfields are linear combinations of the MSSM superfields (defined in the earlier subsection after Eq. (416)), and hence are coupled through the MSSM superpotential in Eq. (103).

$$W \supset \lambda_1 H_u\varphi\Sigma_1 + \lambda_2\Psi\varphi\Sigma_2 + ..., \tag{419}$$

where $\Sigma_{1,2}$ are some MSSM superfields such that $\Sigma_1 \neq \Psi$ and $\Sigma_2 \neq H_u$, since φ is a non-gauge-singlet.

[93] A remarkable feature in Eq. (417) is that SUSY naturally relates the strength of cubic $\phi\chi^2$ and quartic $\phi^2\chi^2$ interactions, which is required for complete decay of the inflaton field. One can also include couplings of the inflaton to fermionic partners of χ. Regarding the prospects for fermionic preheating the same conclusions hold as that of a bosonic case.