The universe on edge: Limits of the effective field theory approach in the very early universe

Oberreuter, J.M.

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APPENDIX E

MASS EIGENMODES IN A STABILIZED SECTOR

In this appendix we provide some intermediate results in the calculation of (3.38–3.39). Using the expressions as stated in appendix D, to first order in $|G_q|$, the second derivatives of the potential are given by

$$V_{qq} = e^G \left[ (2 + e^{-G} V) \nabla_q G_q + (\nabla_q \nabla_q G_q) G_q^3 \right] + \mathcal{O}(|G_q|^2), \quad (E.1)$$

$$V_{q\bar{q}} = e^G \left[ G_{q\bar{q}} (1 + e^{-G} V) + G_q^\bar{q} (\nabla_{q\bar{q}} G_q) \right] + \mathcal{O}(|G_q|^2). \quad (E.2)$$

Using the supersymmetry breaking restriction (3.35) in (E.1) and (E.2), we find

$$V_{qq} = e^G G_{q\bar{q}} \left[ (2 + e^{-G} V) (1 + e^{-G} V) G_{q\bar{q}}^3 - G_{q\bar{q}} (\nabla_q \nabla_q G_q) G_q^3 \right] + \mathcal{O}(|G_q|^2), \quad (E.3)$$

$$V_{q\bar{q}} = e^G G_{q\bar{q}} (1 + e^{-G} V) + (1 + e^{-G} V)^2 G_{q\bar{q}} G_{q\bar{q}} G_{q\bar{q}} + \mathcal{O}(|G_q|^2)$$

$$= e^G G_{q\bar{q}} (2 + e^{-G} V) (1 + e^{-G} V) + \mathcal{O}(|G_q|^2), \quad (E.4)$$

and hence

$$|V_{qq}| = e^G G_{q\bar{q}} (2 + e^{-G} V) (1 + e^{-G} V) \times$$

$$\times \sqrt{1 - \frac{2G_q^\bar{q} \text{Re}\{ (\nabla_q \nabla_q G_q) G_q^\bar{q} G_q^3 \}}{(2 + e^{-G} V)(1 + e^{-G} V)} + \frac{|G_q^\bar{q} (\nabla_q \nabla_q G_q) G_q^3|^2}{(2 + e^{-G} V)^2(1 + e^{-G} V)^2} + \mathcal{O}(|G_q|^2)}$$

$$= e^G G_{q\bar{q}} \left[ (2 + e^{-G} V) (1 + e^{-G} V) - G_{q\bar{q}}^3 G_q^3 \right] + \mathcal{O}(|G_q|^2). \quad (E.5)$$

Then (3.37) is evaluated to be

$$m_q^- = e^G G_{q\bar{q}}^3 \text{Re}\{ (\nabla_q \nabla_q G_q) G_q^3 \} |G_q^\bar{q}| + \mathcal{O}(|G_q|^2), \quad (E.6)$$

$$m_q^+ = e^G \left[ 2(2 + e^{-G} V)(1 + e^{-G} V) - G_{q\bar{q}}^3 \text{Re}\{ (\nabla_q \nabla_q G_q) G_q^3 \} |G_q|^2 \right] + \mathcal{O}(|G_q|^2). \quad (E.7)$$