Inflation in Uplifted Supergravity

Adolfo Guarino
IFT, Madrid

with de Carlos, Casas, Moreno, Seto: hep-th/0702103

Mytilene , 09/2007

Contents

- Moduli stabilisation
- A SUGRA model with anomalous U(1)
- Does it inflate?
- Minimal working model
- Conclusions

Moduli stabilisation

- Superstring models include a plethora of moduli fields
- Associated with the structure of the internal space (size, angles, singularities) + deformations

Challenge

Realistic model:

- Fix dynamically the moduli
- dS vacua

Implications for:

Cosmology

Phenomenology (SUSY breaking, etc)

Mechanisms

- Non perturbative effects (instantons, condensates)
- Geometric and non-geometric fluxes, torsion, etc

Generic problem

it is complicated to find ~~SUSY~~ dS vacua

A popular model: KKLT

(Kachru, Kallosh, Linde, Trivedi)

- Combines BOTH fluxes and n.p. effects
- dS: uplifting comes from anti D3 branes
- From the effective SUGRA theory point of view this induces a term:

$$V = V_F + \frac{k}{T_R^2}, \quad T_R \equiv Re(T)$$

- This term breaks SUSY explicitly

dS vacua from uplifting D-terms

- Ingredients: gaugino condensation and anomalous U(1) in a gauge invariant way.
- SU(N) x U(1) gauge group
- Content: T-modulus + N_f pairs $\{Q, \bar{Q}\}$
- SUSY breaking: non-vanishing F-terms and D-terms

The consistent model

Achucarro et al.

(type IIB string)

$$K = -3\log(T+\bar{T}) + \sum_{i=1}^{N_f}(|Q_i|^2 + |\bar{Q}_i|^2) = -3\log(T+\bar{T}) + N_f|M|^2$$

matter condensate

$$W = W_0 + W_{np}$$

$$W_{np} = (N-N_f)\left(\frac{2\Lambda^{3N-N_f}}{M^{2N_f}}\right)$$

$$= (N-N_f)\left(\frac{2}{M^{2N_f}}\right)^{\frac{1}{N-N_f}} e^{\frac{-4\pi k_N T}{N-N_f}}$$

gauge invariant

Periodic in [a Im(T) + b phase(M)]

The scalar potential

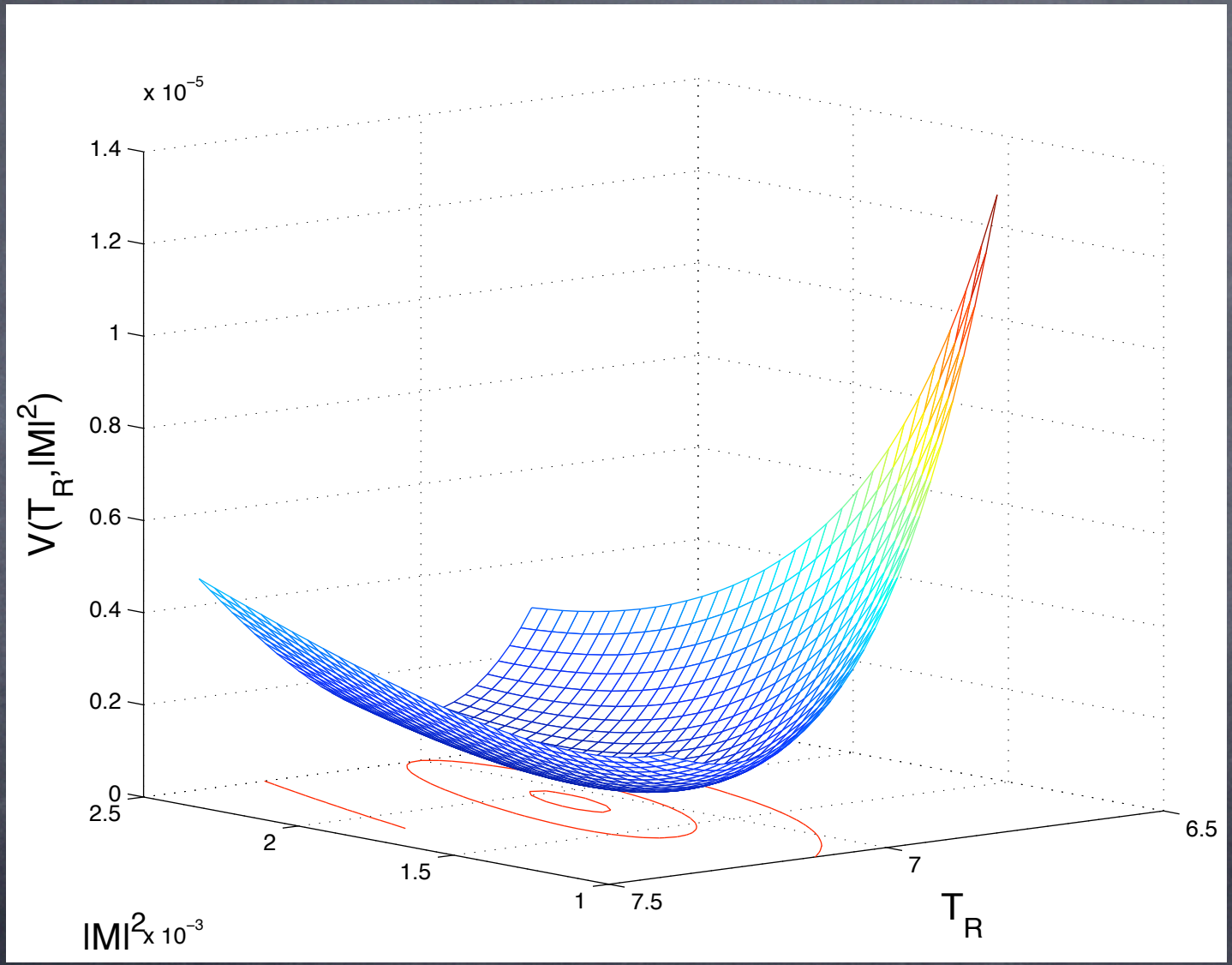
$$V = V_F + V_D$$

$$V_F = \mathrm{e}^K \{ K^{I\bar{J}} D_I W D_{\bar{J}} \bar{W} - 3|W|^2 \}$$

$$V_D \sim \frac{1}{T_R} \left(N_f (q + \bar{q}) |M|^2 - 3 \frac{\delta_{GS}}{2 T_R} \right)^2$$

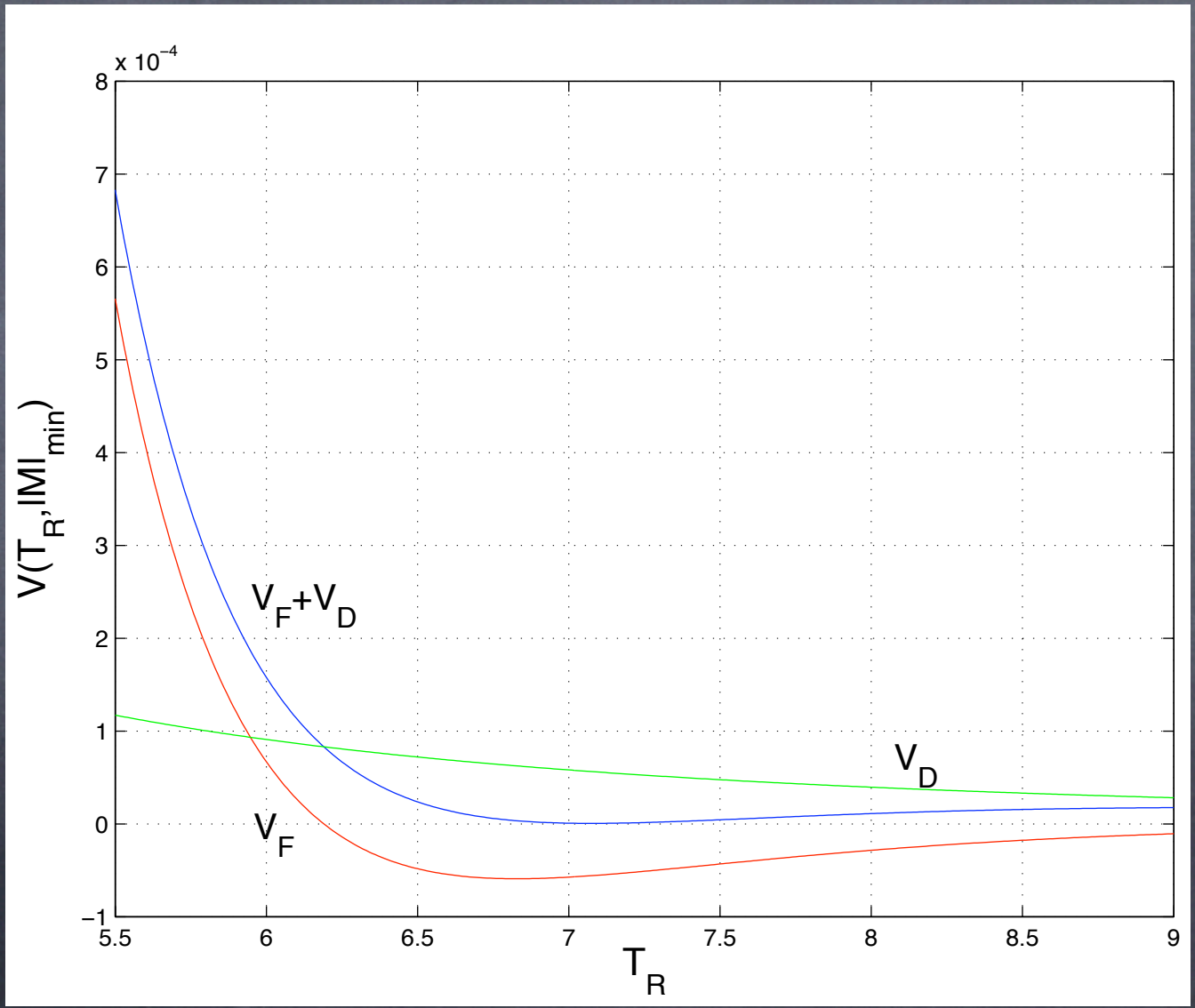
The relative sign of this terms is fixed by the anomaly cancellation condition $\delta_{GS} \sim -(q + \bar{q})$.

T-M stabilization



$N = 15, N_f = 1 \qquad q = \bar{q} = 2 \qquad W_0 = 0.3$

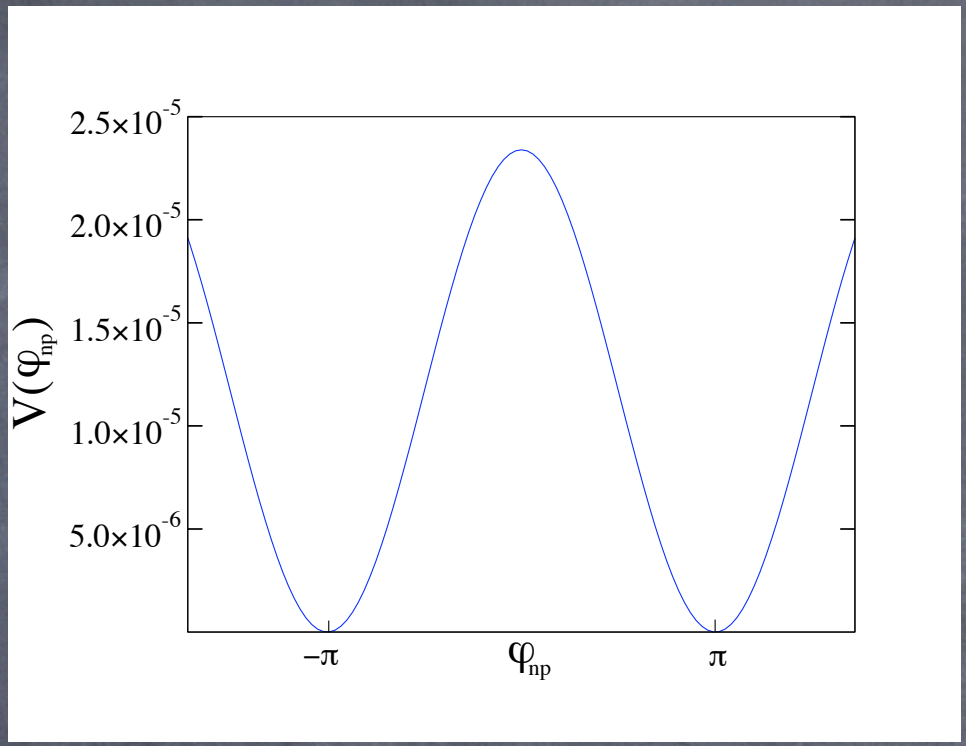
D-term uplift



Candidates to inflaton

- In this framework moduli can be stabilised at suitable values.
- The energy of the vacuum is naturally positive but could be tuned to zero.
- Can any of these moduli be a good inflaton?

Degenerated vacua



There is a periodic vacuum structure given by

$$W_{np} \rightarrow e^{2\pi i} W_{np}$$

Topological inflation ?

Eternal topological inflation

Linde'94
Vilenkin'94

- Topological inflation can occur within a domain wall separating two different vacua
- The thickness of the wall should be larger than the local horizon at the top of the domain wall
- The core of the domain is stable and eternally inflating, but the regions around are not and will roll toward the minima.

>>This model as such does not contain an inflaton

de Carlos, Casas, Guarino, JM and Seto: '07

The minimal extension

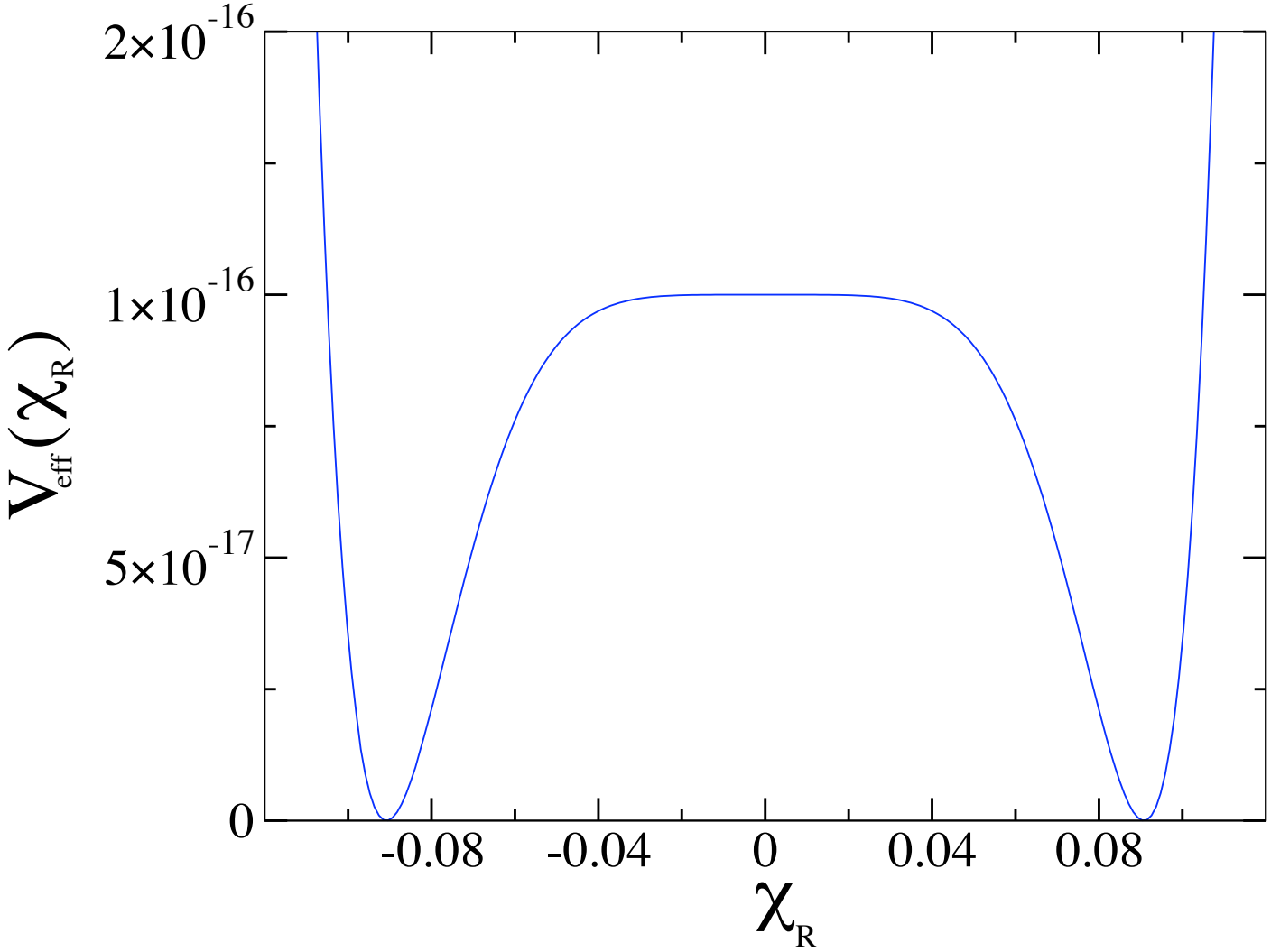
We introduce a singlet, χ with superpotential

$$W_{sing} = \lambda_2 \chi^2 + \lambda_4 \chi^4 + \lambda_6 \chi^6$$

$$W = W_0 + W_{\rm np} + W_{\rm sing}$$

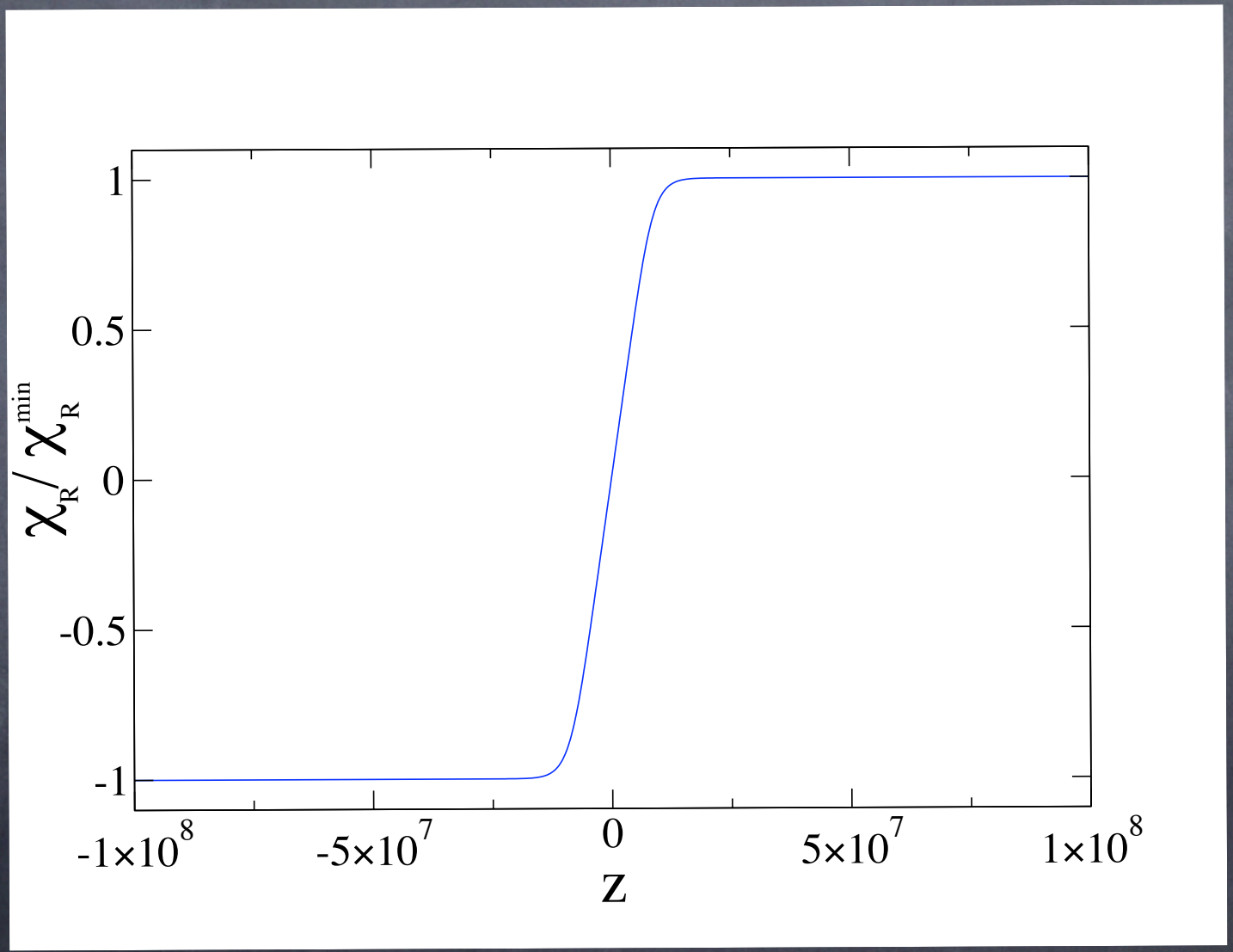
(W_0, λ_2) existence of saddle at $|\chi| = 0$

(λ_4, λ_6) existence of global Minkowski minimum



$$W_{sing} = \lambda_2 \chi^2 + \lambda_4 \chi^4 + \lambda_6 \chi^6$$

The domain wall solution



Matter Lagrangian:

$$|g|^{-1/2}\mathcal{L}_{\rm matter} = K_{ij}\, g^{\mu\nu}\partial_\mu\Phi^i\partial_\nu\bar{\Phi}^j - V = \frac{1}{2}\mathcal{G}_{ij}\, g^{\mu\nu}\partial_\mu\phi^i\partial_\nu\phi^j - V$$

Evolution equations:

$$\ddot{\phi}^i + 3\,H\,\dot{\phi}^i + \Gamma^i_{jk}\,\dot{\phi}^j\,\dot{\phi}^k + \mathcal{G}^{ij}\,\frac{\partial V}{\partial\phi^j} = 0$$

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{1}{3}\left[\frac{1}{2}\,\mathcal{G}_{ij}\,\dot{\phi}^i\dot{\phi}^j + V\right]$$

$$ds^2 = dt^2 - a(t)^2 dx_i dx^i$$

$$a(t) = e^{N_e(t)}$$

$$H = \frac{dN_e(t)}{dt}$$

In terms of the number of e-folds, N_e

$$\phi^{i\prime\prime} + \left[1 - \frac{1}{6}\mathcal{G}_{jk}\phi^{j\prime}\phi^{k\prime}\right]\left[3\phi^{i\prime} + 3\mathcal{G}^{ij}\frac{1}{V}\left(\frac{\partial V}{\partial \phi^j}\right)\right] + \Gamma^i_{jk}\,\phi^{j\prime}\phi^{k\prime} = 0$$

Slow roll approximation: 1st order

$$\phi^{\prime i} + \mathcal{G}^{ij}\frac{1}{V}\frac{\partial V}{\partial \phi^j} = 0$$

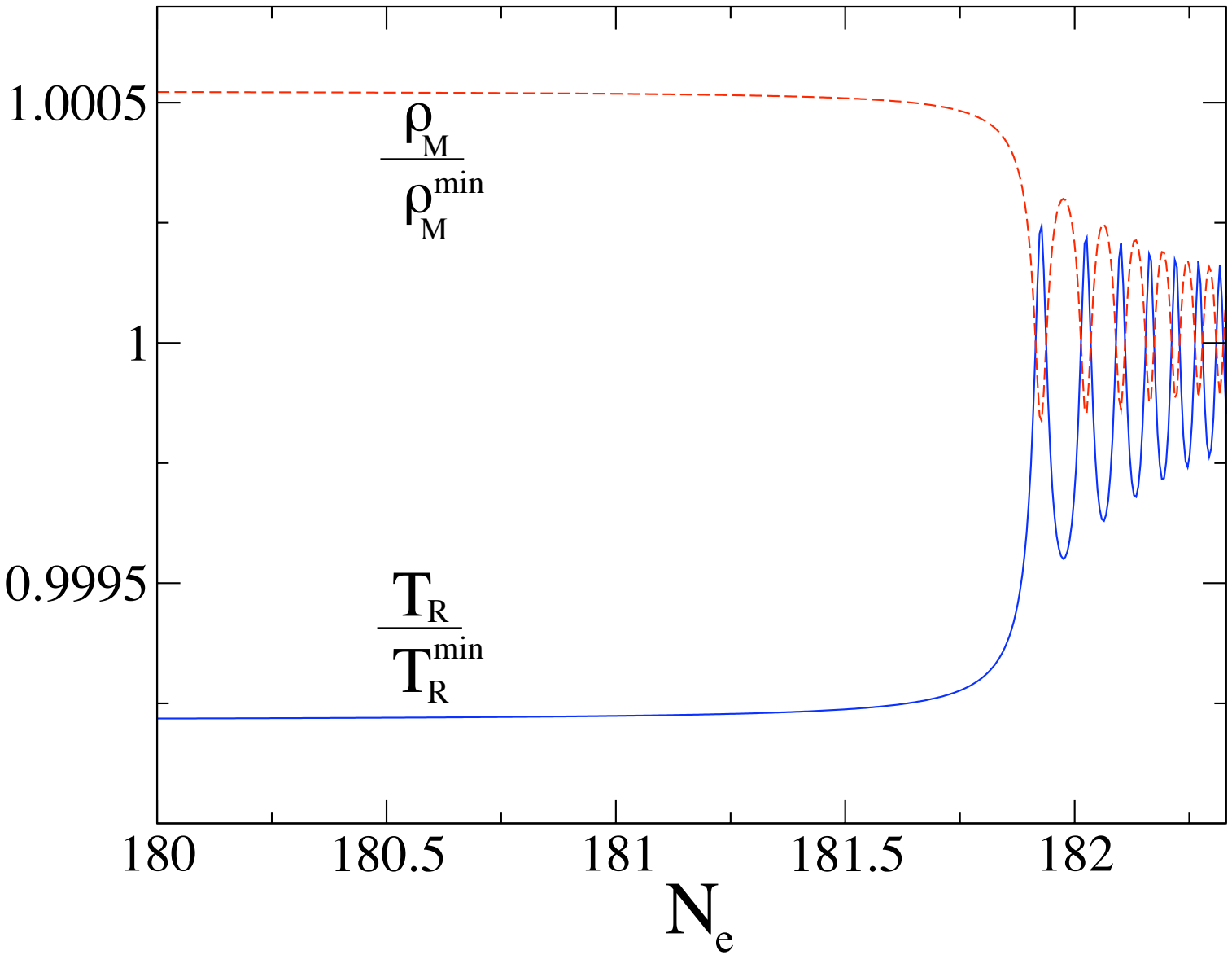
The axionic directions do not intervene in the evolution (one is flat, two get fixed)

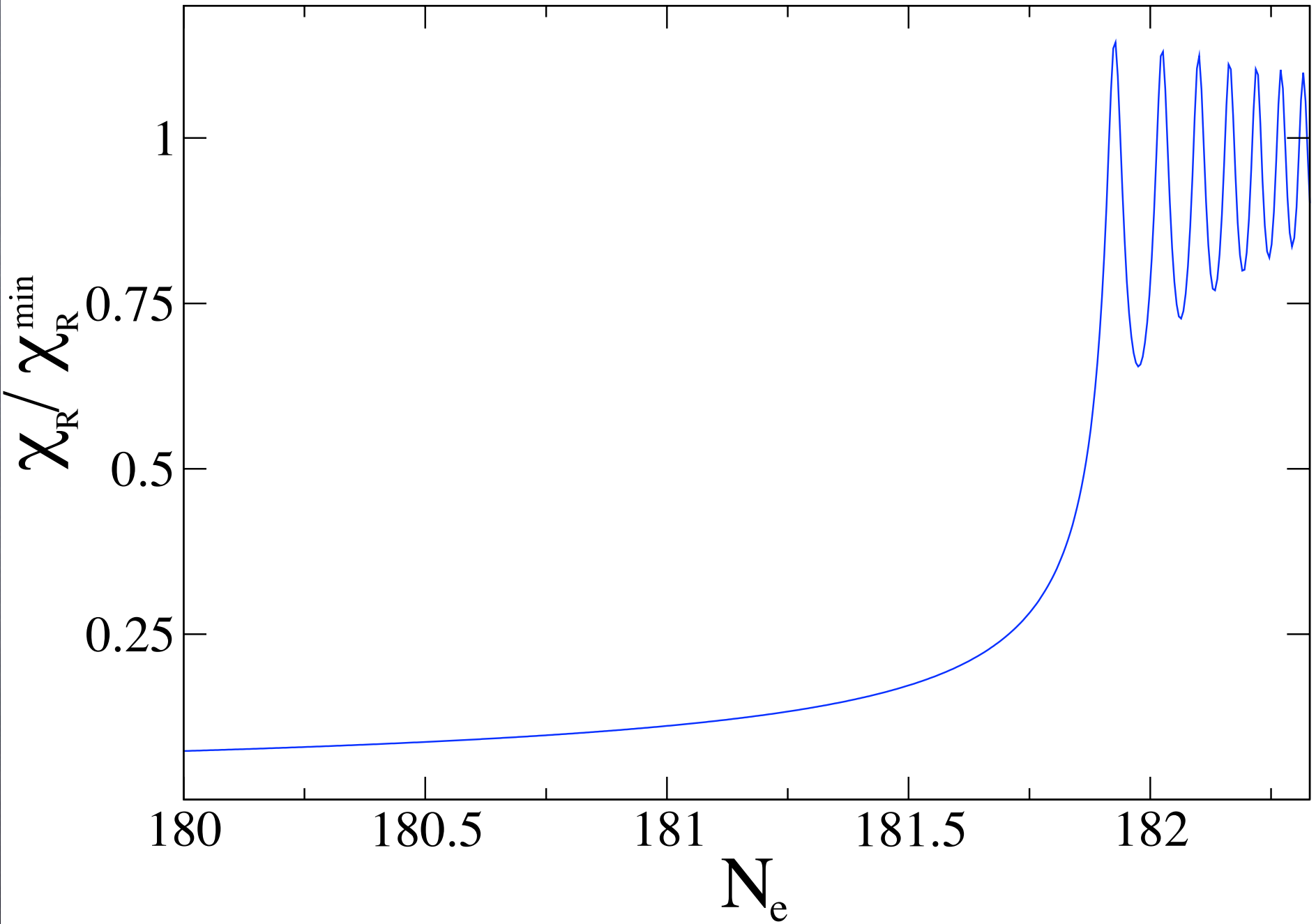
$(T_R, |M|, \chi)$ have a coupled evolution

χ_R is our inflaton

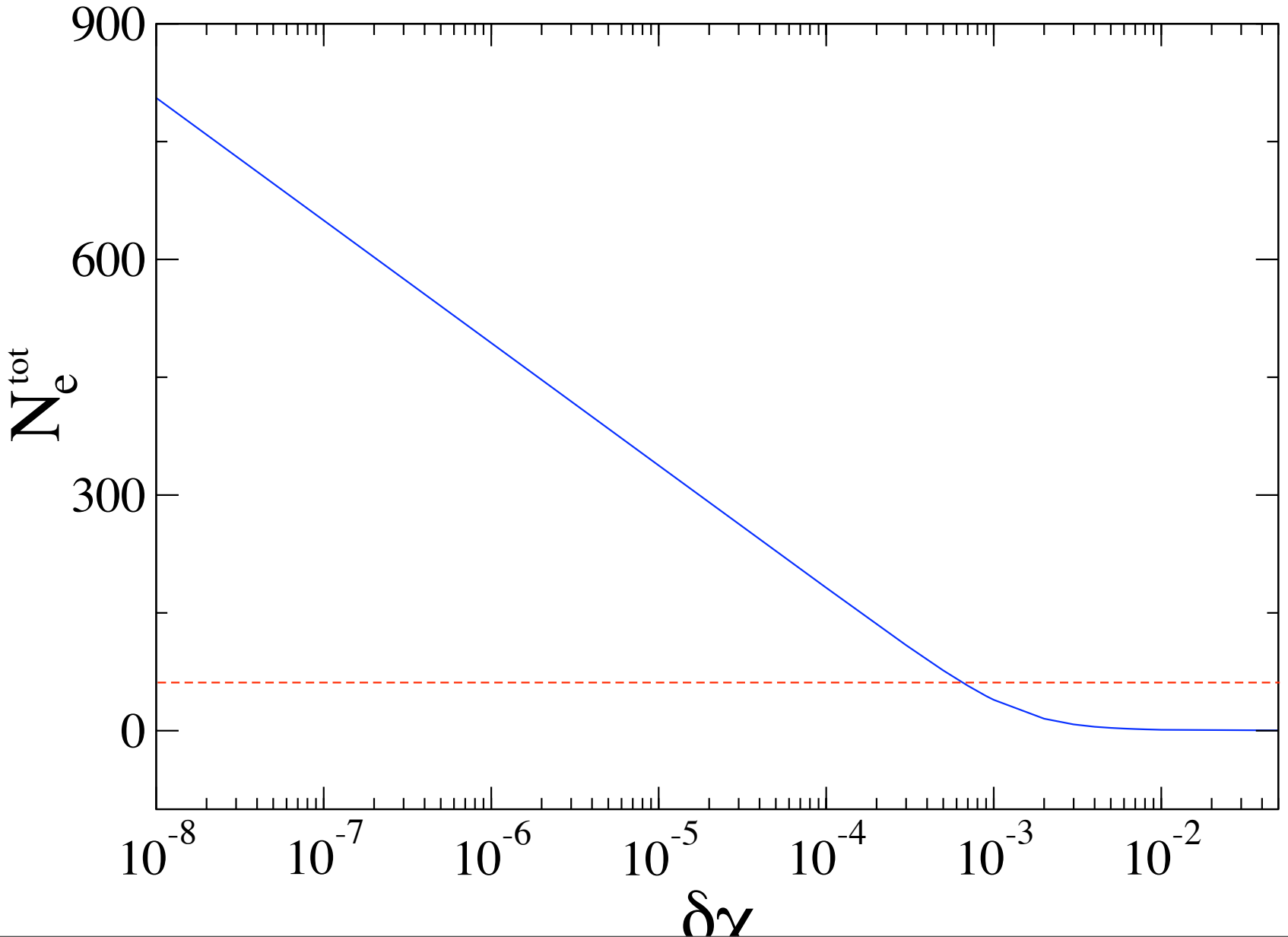
$N = 20, N_f = 1, k_N = 1/2, q = 1, \bar{q} = 1/10$ $W_0 = 0.420, \lambda_2 = -0.215$

$\lambda_4 = 0.055, \lambda_6 = -0.009$

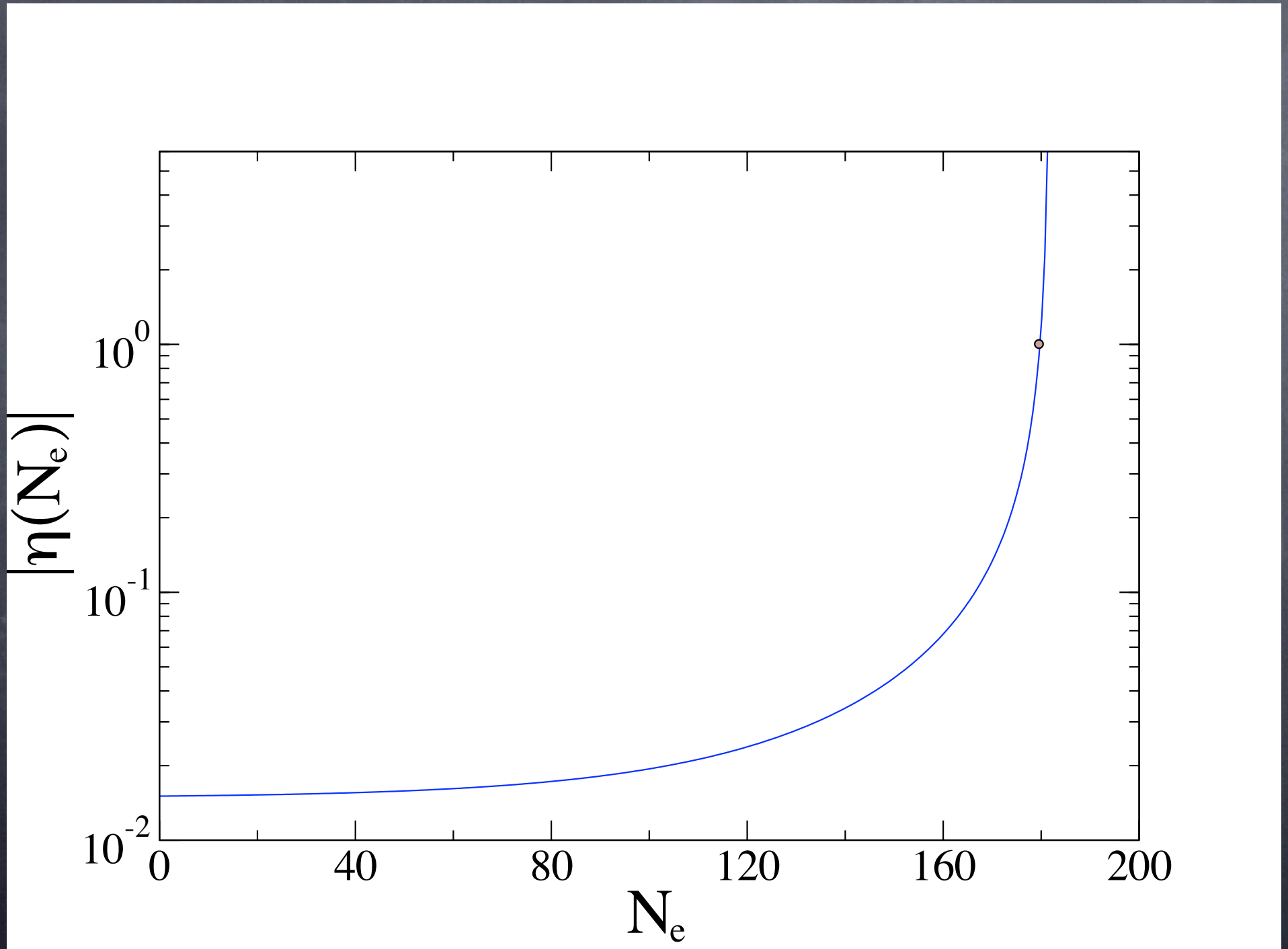



1
0.75
0.5
0.25
χ_R / χ_R^{min}
180
180.5
181
181.5
182
N_e

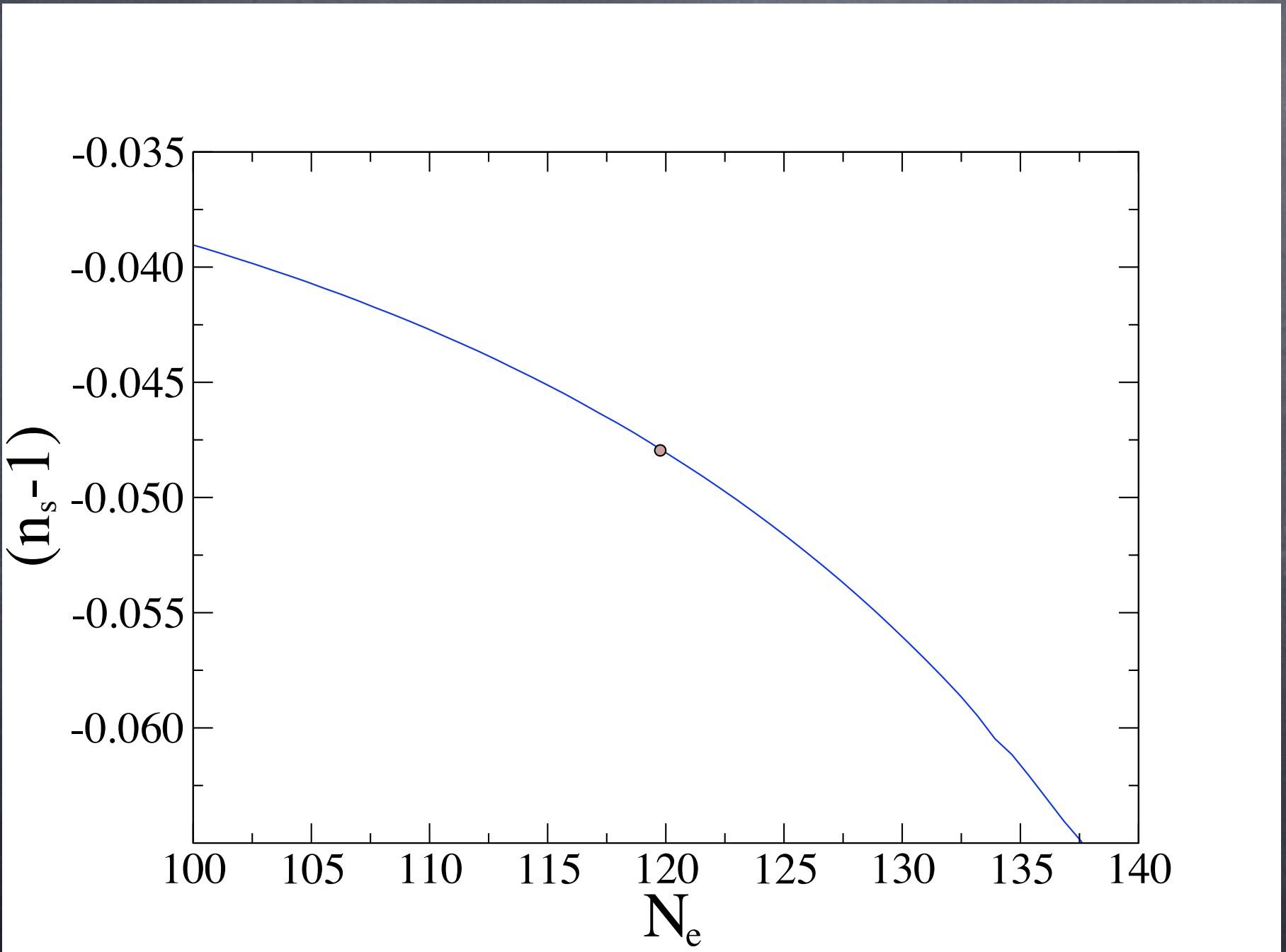
The defect as a set of initial conditions...



End of inflation ~180 e-folds



Scalar power spectrum compatible with WMAP



Conclusions

- Inflation within SUGRA is moving towards realistic scenarios
- Many moduli potentials are now considered with Minkowski/dS vacua
- Eta problem and initial conditions under control
- Models still slightly "ugly" (fine tuning)
- Altogether promising results