De Sitter Compactifications

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Compactifications of higher dimensional theories

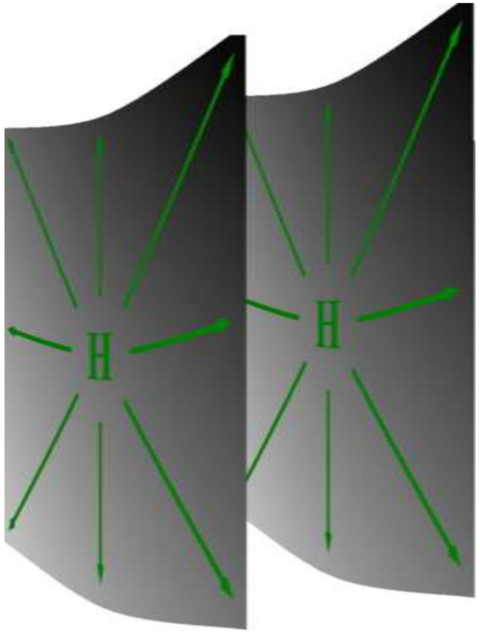
Particle Physics:			Cosmology:	
Particle spectrum	**Vacuum**	**Low energy effective theory:**	**Inflation/CC**	**Stand. Cosmology**
3 Lepton families	$\mathcal{N} = 1$ **Susy**		**no Susy**	BBN/CMB
Chiral fermions	Minkowski space		de Sitter space	LSS/SN
SM gauge fields	AdS space			

Difference with sever Consequences:

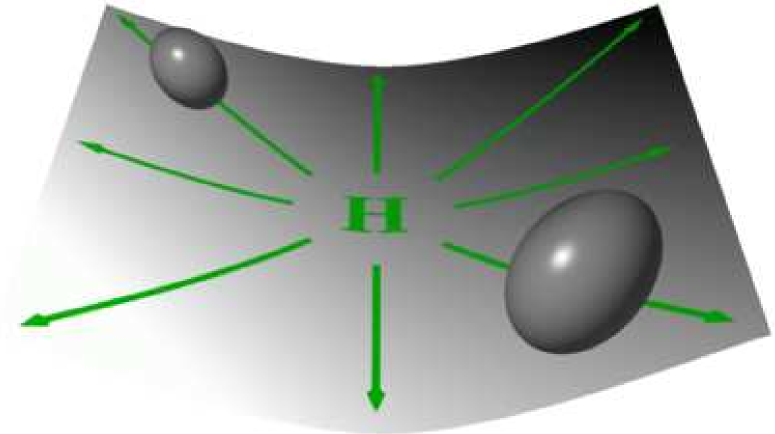
Gravitational instability in scalar sector

- Enhanced moduli stabilization problem
- Non-trivial dynamics
- Dynamical exit from inflation

Braneworlds



Kaluza-Klein Compactifications



Generic Background:

$$ds^2 = e^{2B(y)} \left\{ \underbrace{-dt^2 + e^{2Ht} d\vec{x}^2}_{\gamma_{\mu\nu}(x)dx^\mu dx^\nu} + g_{mn}(y) dy^m dy^n \right\}$$

Analysis of Perturbations: Linearized Einstein equations (+ boundary conditions)

$$\delta G_{MN} = \delta T_{MN}$$

Metric Fluctuations:

$$\begin{aligned} ds^2 = \; & e^{2B(y)} \left[\left(1+2\Psi-\tfrac{1}{2}q\Phi\right)\gamma_{\mu\nu} + h_{(\mu\nu)} \right] dx^\mu dx^\nu \\ & + e^{2B(y)} \left[(1+2\Phi)\, g_{mn} + h_{(mn)} \right] dy^m dy^n \\ & + e^{2B(y)} 2V_{\mu n} dx^\mu dy^n \end{aligned}$$

Matter Perturbations:

- Scalar Fields $\delta\phi$
- Form Fluxes $\delta F_{M_1 \cdots M_q}$
- etc.

Scalars

$$m_0^2 = -\frac{12H^2}{1+2/q} + m^2(R_q) + m^2(B)$$

Vectors

$$m_0^2 = 0$$
$$m_0^2 \propto H^2$$

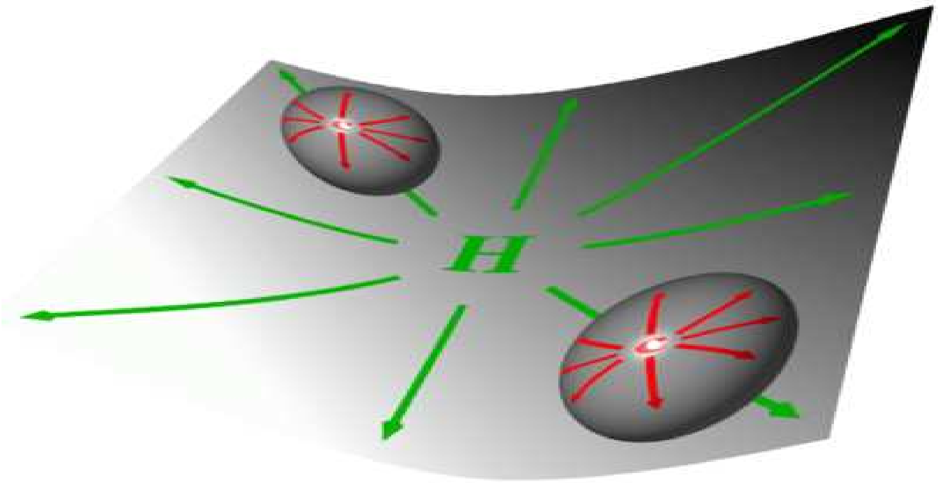
Tensors

$$m_0^2 = 0$$
$$m_0^2 \propto H^2$$

Freund-Rubin Compactifications

- **Action:**

$$S = \int d^4x d^q y \sqrt{|G|} \left\{ \frac{1}{2} R - \frac{1}{2q!} F_q^2 - \Lambda \right\}$$



- **Ansatz:**

$$\begin{aligned} ds^2 &= -dt^2 + e^{2Ht} d\vec{x}^2 + \rho^2 d\Omega_q^2 \\ F_{m_1 \cdots m_q} &= c\varepsilon_{m_1 \cdots m_q} \end{aligned}$$

- **Equations of Motion:**

$$\begin{aligned} (q-1)\ \rho^{-2} - 3H^2 &= c^2 \\ (q-1)^2 \rho^{-2} + 9H^2 &= 2\Lambda \end{aligned}$$

☞ Two free parameters

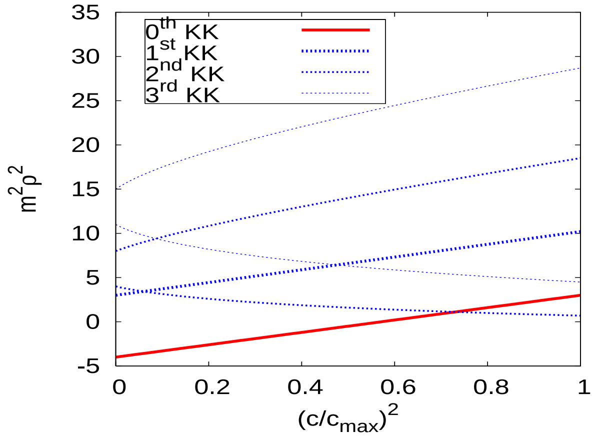
☞ $H^2 > 0 \Longrightarrow c^2 < c_{max}^2 = (q-1)\rho^{-2}$

Form flux fluctuations:

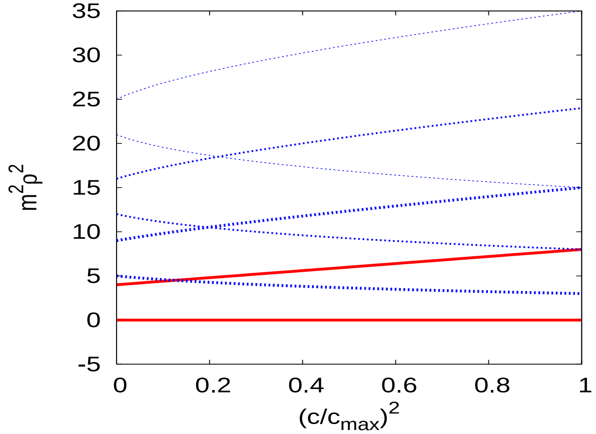
$$f_{m_1 \cdots m_q} = q \nabla_{[m_1} a_{m_2 \cdots m_q]} = q\, \varepsilon^m{}_{[m_2 \cdots m_q} \nabla_{m_1]} \nabla_m b$$

$$f_{\mu m_2 \cdots m_q} = \varepsilon^m{}_{m_2 \cdots m_q} \nabla_\mu \nabla_m b + (-)^{q-1}(q-1) \varepsilon^{mn}{}_{[m_2 \cdots m_{q-1}} \nabla_{m_q]} \nabla_m b_{\mu n}$$

Scalars



Vectors



Lowest modes:

$$m_0^2 = -6H^2 + 4\frac{q-1}{q+2}c^2$$

$$m_0^2 = 0$$

$$m_0^2 = 6H^2 + 4c^2$$

KK spectrum:

(mixed mass eigenstates)

$$\Phi, b$$

$$V_{\mu n}, b_{\mu n}$$

Consequences

☞ **Meaning of the Tachyonic Scalar Mode:**

- Φ — Volume modulus field
- Indication for instable background configuration

☞ **Stabilization Mechanisms**

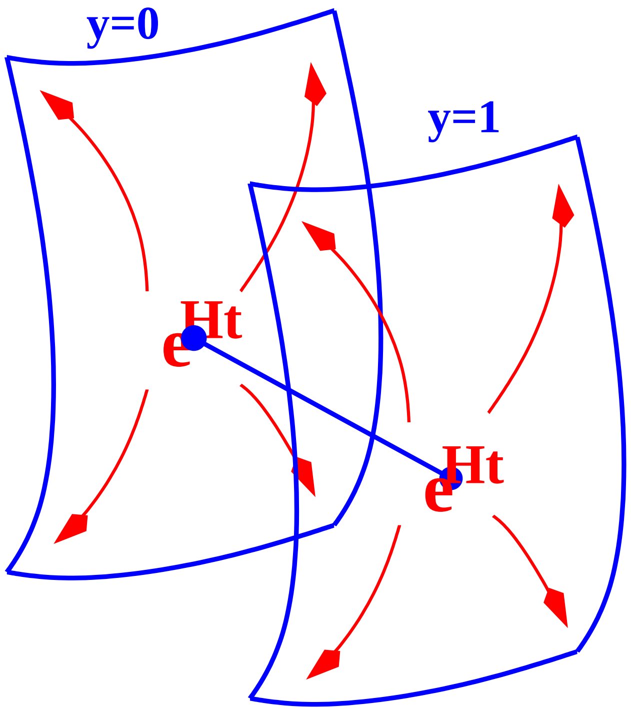
- Stabilizing scalar fields (e.g. Goldberger-Wise)
- Stabilizing form fluxes

☞ **Generic Attractors**

- Singular collapse of the extra dimensional space (Kasner asymptotics)
- Reconfiguration to a point in parameter space, where the tachyonic instability disappears (e.g. $H \to 0$)

Example: Braneworlds

- Two end-of-the-world branes
- $S^1/\mathbb{Z}_2$ – orbifold



Distance between branes:

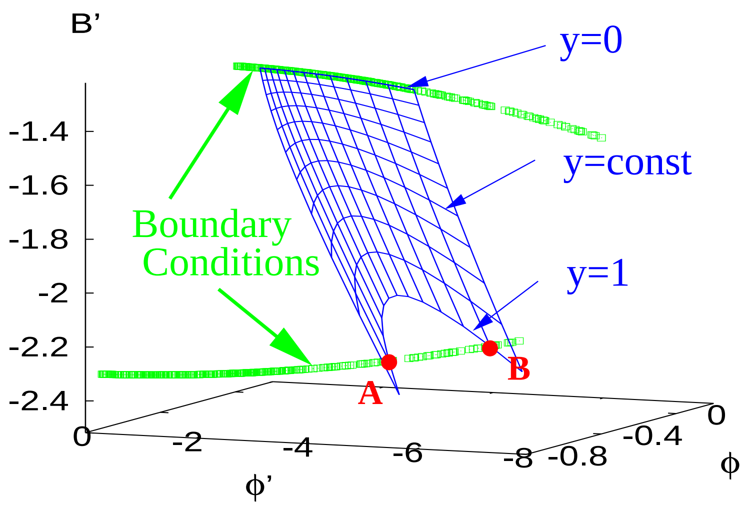
$$D(t) = \int_0^1 e^{B(y,t)} dy$$

$$\begin{aligned} ds^2 &= e^{2B(y)} \left[dy^2 - dt^2 + e^{2Ht} d\vec{x}^2 \right] \\ \phi &= \phi(y) \\ V &= \tfrac{1}{2} m^2 \phi^2 + \Lambda \\ U_i &= \zeta_i (\phi - \nu_i)^2 + \lambda_i \end{aligned}$$

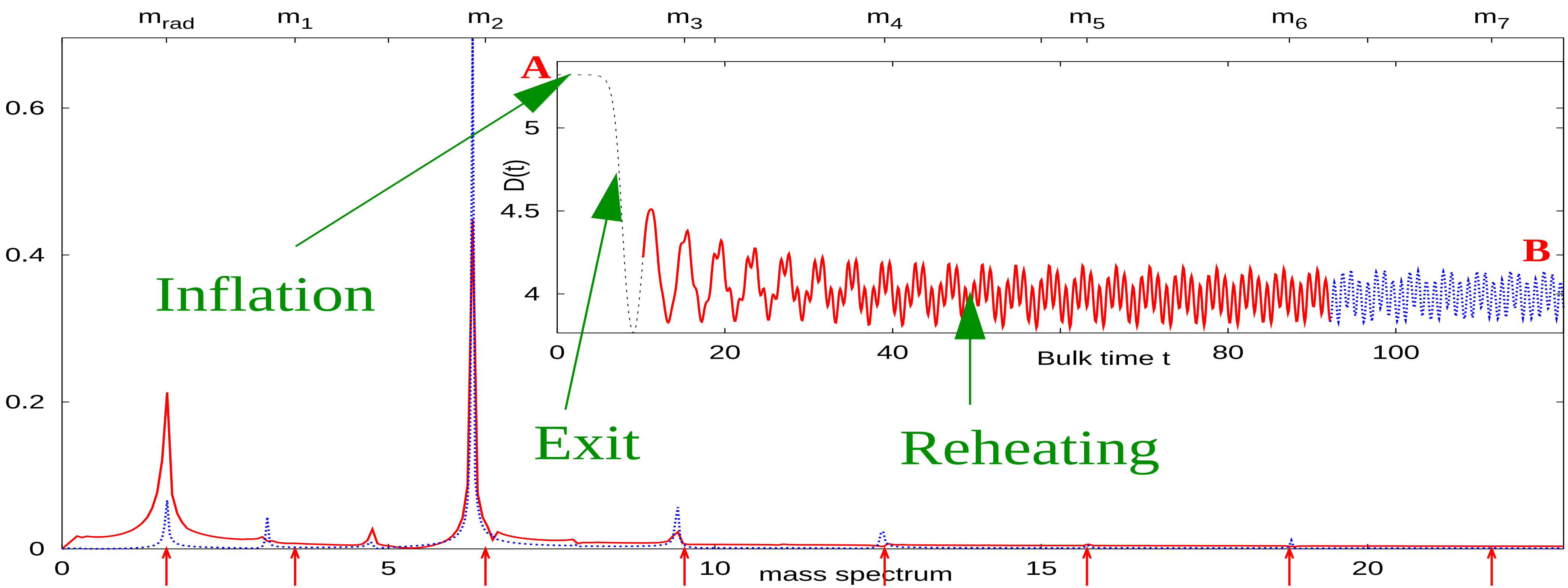
Find Braneworld for given bulk and brane potentials

- Non-linear boundary value problem
- In general, more than one solution
- In case of two solution $\Longrightarrow$ non-linear transition from solution with large H to solution with smaller H

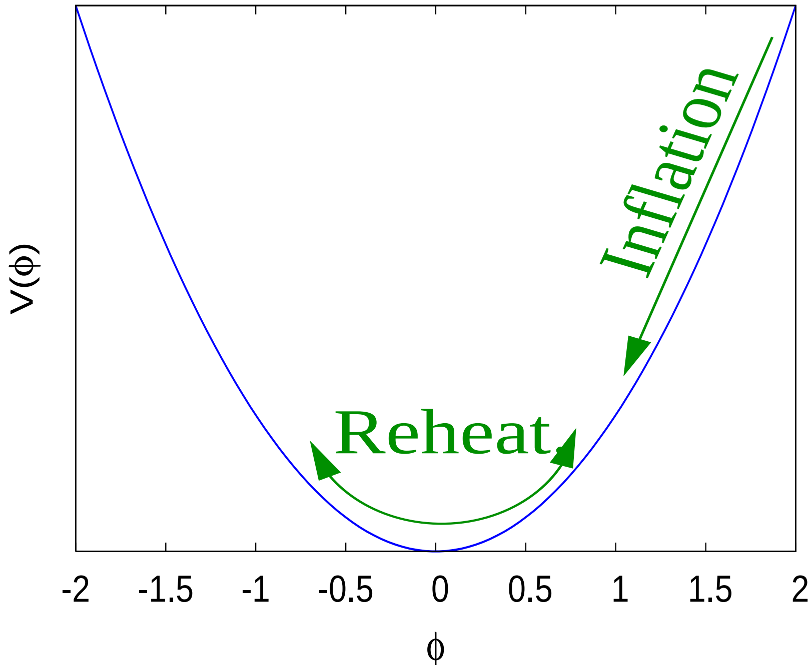
Application

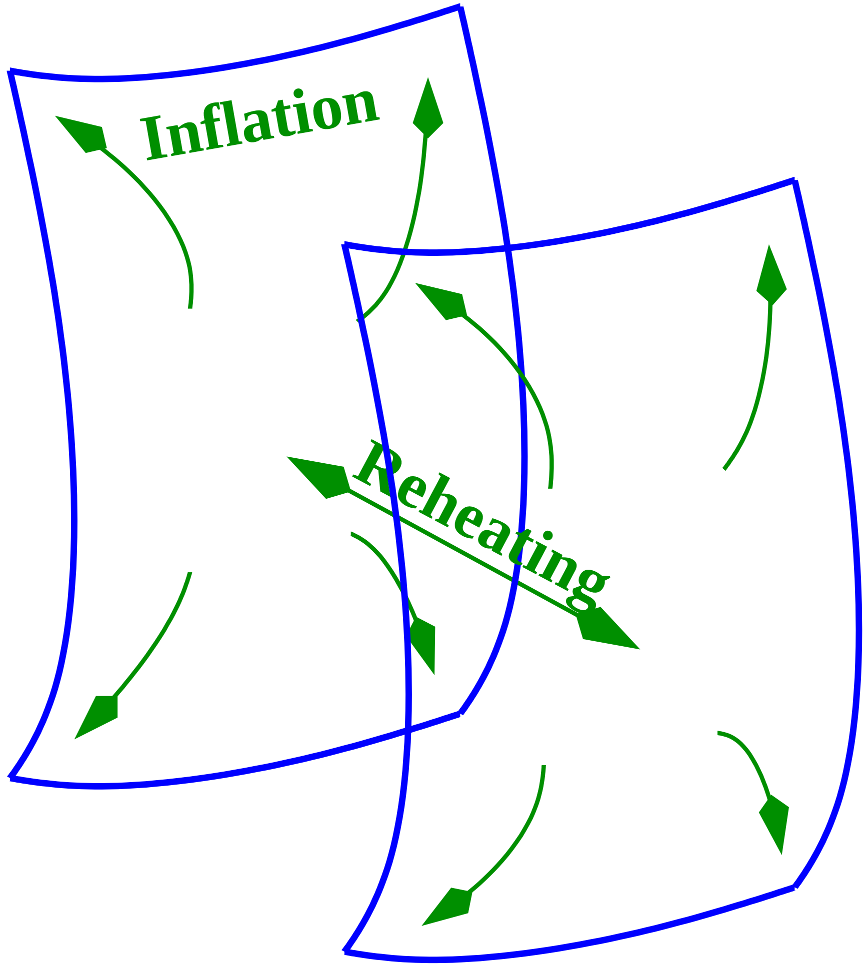


- **A:**
  - **Tachyonic instability of de Sitter compactifications**
  - **Generic Asymptotics (Transition to $m > 0$)**
- **B:**
  - **Radion oscillations around stable vacuum ($H = 0$)**
  - **Coupling to SM fields**
- **Reheating - no parametric resonance!**
- **Finetuning!**



Application





- Induced brane curvature $\Longrightarrow$ Inflation
- Tachyonic instability $\Longrightarrow$ Exit from Inflation
- Radion oscillations $\Longrightarrow$ Reheating
- Bulk metric fluctuations $\Longrightarrow$ Primordial perturbations