Inflationary limits on compact extra dimensions

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One of the question remaining not clarified yet is:

why specific number of dimensions are compactified and stable while others expand?

Which specific property of subspace leads to its quick growth?

Classical evolution of subspaces,
Lyakhova, Y., Popov, A.A. & Rubin, S.G.
Eur. Phys. J. C (2018) 78: 764.

Initial conditions are key element!

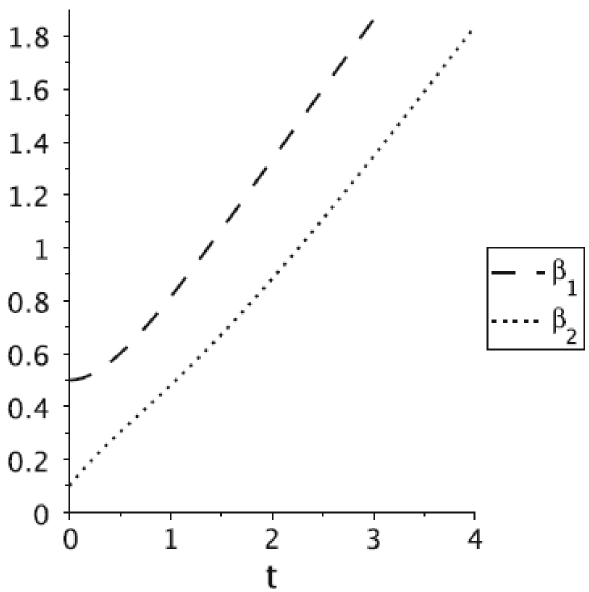
$$ds^2 = dt^2 - e^{2\beta_1(t)} d\Omega_1^2 - e^{2\beta_2(t)} d\Omega_2^2$$

$$S = \frac{m_D^4}{2} \int d^D Z \sqrt{|g|} f(R),$$

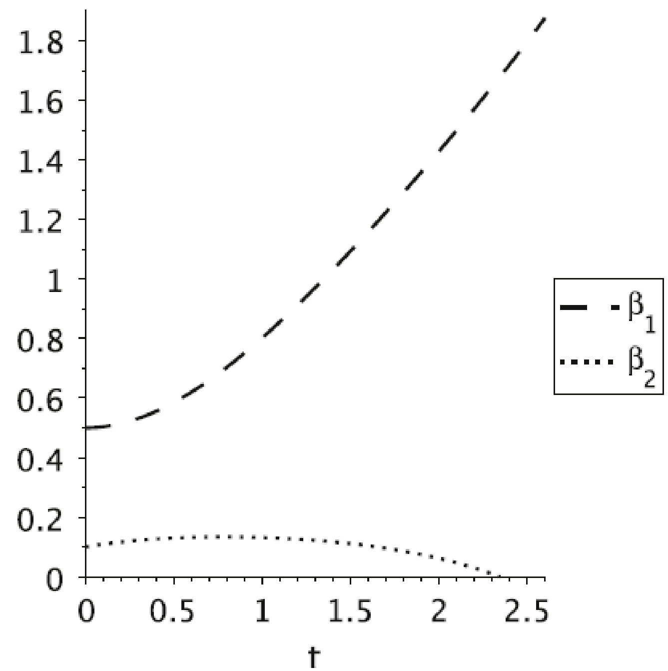
$$-\frac{1}{2} f(R) + f_R[e^{-2\beta_1(t)}(d_1 - 1) + \ddot{\beta}_1 + \dot{\beta}_1(d_1\dot{\beta}_1 + d_2\dot{\beta}_2)] \\ +[(1 - d_1)\dot{\beta}_1 - d_2\dot{\beta}_2] f_{RR}\dot{R} - f_{RRR}\dot{R}^2 - f_{RR}\ddot{R} = 0, \tag{4}$$

$$-\frac{1}{2} f(R) + f_R[e^{-2\beta_2(t)}(d_2 - 1) + \ddot{\beta}_2 + \dot{\beta}_2(d_1\dot{\beta}_1 + d_2\dot{\beta}_2)] \\ +[(1 - d_2)\dot{\beta}_2 - d_1\dot{\beta}_1] f_{RR}\dot{R} - f_{RRR}\dot{R}^2 - f_{RR}\ddot{R} = 0, \tag{5}$$

$$-\frac{1}{2} f(R) + \left[d_1\ddot{\beta}_1 + d_2\ddot{\beta}_2 + d_1\dot{\beta}_1^2 + d_2\dot{\beta}_2^2\right] f_R \\ - \left(d_1\dot{\beta}_1 + d_2\dot{\beta}_2\right) f_{RR}\dot{R} = 0 \tag{6}$$



$\dot{\beta}_2(0) = 0.5$



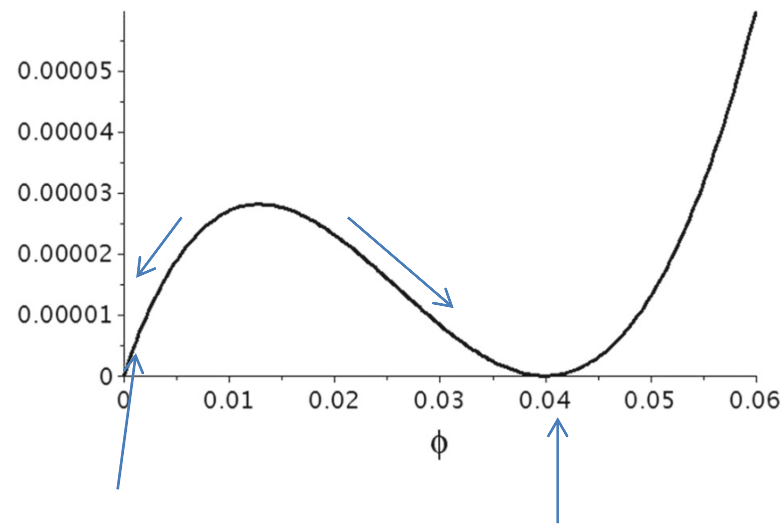
$\dot{\beta}_2(0) = 0.1$

Extra dimensions of a stationary size where not found

$$\mathcal{L}_{GB} = k\sqrt{-g}\left\{R^2 - 4R_{AB}R^{AB} + R_{ABCD}R^{ABCD}\right\}$$

$$R_{d_1} \ll R_{d_2}$$

$$S_E = \frac{v_{d_2}}{2}\int d^{d_0}x\sqrt{-g_0^{(E)}}\,sign(f')[R_{d_0}^{(E)} + K_E(\phi_2)\dot{\phi}_2^2 - 2V_E(\phi_2)]$$



Growing extra space

Comact extra space of finite radius

K.B. Bronnikov , S.G. Rubin, Self-stabilization of extra dimensions. Phys.Rev. D73:124019,2006. e-Print: gr-qc/0510107.

According to LHC data, the lows of physics remains unaltered up to the distance of order 10^{-18} cm. This means that the same limit relates to a size of extra dimensions provided that they exist.

The cosmological observations impose much more serious restrictions on the extra space size.

Let us consider the action

$$S = \int d^D x \sqrt{-g} L(g_{AB}(x), u^a(x), u,^a_B(x)). \tag{2}$$

The field $u^a(x)$ is a tensor field or several fields acting on a manifold with fixed metric. We assume that the metric does not depend on one of the coordinate, say x_n which we denote as w.

$$Q(t) = v_d^{-1} \int d^3x d^{D-5} y dw \sqrt{-g} j^0$$

$$j^B \equiv \left(\frac{\partial L}{\partial u^a,_B} u^a,_w - \delta^B_w L \right)$$

The charge is NOT conserved during an evolution of extra space

$$ds^2 = dt^2 - a(t)^2(dr^2 + r^2 d\Omega_4^2) - e^{2\beta(t,\phi,\theta)} d\Omega_2^2$$

in the units $m_D = 1$. $a(t) = H^{-1}e^{Ht}$ for the de Sitter space.

Charge (internal momentum) at the beginning of inflation is almost zero. Below we calculate (estimate) the charge value at the end of inflation. This gives us a number of particles - KK excitations - that survive after inflation. To perform this plan we have to solve equations of motion.

$$\Box_6 \chi + \mu^2 \chi = 0, \quad c.c. = 0$$

$$\Delta Q = e^{+3Ht} m_6^4 r_0 H^{-2} \int d\theta d\phi \sin\theta e^{2\beta(t,\theta,\phi)} \partial^0 \chi \partial_\phi \chi^* + c.c.$$

Dimensionless quantity

At the end of inflation Ht~60 $e^{+3Ht} = e^{180} \simeq 10^{78}$

Total energy of baryons in the Universe 10^{80} GeV

$$\frac{r_0}{1cm} < 10\left(\frac{1TeV}{m_6}\right)^4$$

$10^{-33} < r_0$ cm

$\Rightarrow$ $m_6 < 10^8 TeV$

Usual choice is

$1 < m_6 < 10^{16} TeV$

Classical behavior leads to $r_0 >> 1/m_6 > 10^{-8} TeV^{-1} = 10^{-25} cm$

CONCLUSION

-Accidental initial condition are the reason of different evolution of subspaces

-D-dim Planck mass is not close to the 4-dim Planck mass

for D=6 $m_6 < 10^8 TeV$

for compact dimensions

- Classical description of extra space :

$$r_0 >> 1/m_6 > 10^{-8} TeV^{-1} = 10^{-25} cm$$

Thank you