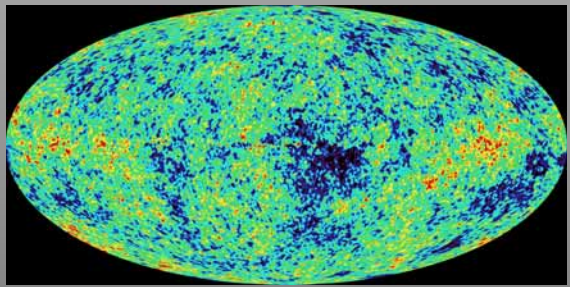
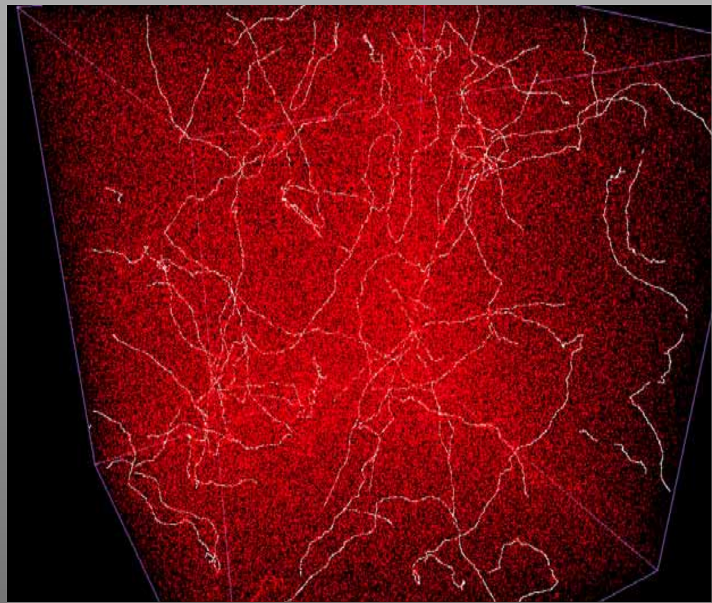
Cosmology can constrain SUSY models:

The truth about the role of cosmic strings





In collaboration with Jonathan Rocher

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Moriond 2004

Within SUSY GUTs, cosmic string formation is unavoidable in all acceptable SSB schemes from the GUT down to the standard model gauge group.

Jeannerot, Rocher, Sakellariadou PRD **68**, 103514 (2003)

See talk by Jonathan Rocher

Mixed models: hybrid inflation + strings

Cosmic strings and/or embedded strings

But …

Embedded defects:

Consider a pattern of symmetry breaking

$$G \to H$$

To construct embedded defects, choose a sub-group

$$G_{emb} \subset G$$

such that $\pi_k(G_{emb}/H_{emb})$ is non-trivial,

where $H_{emb} = H \cap G_{emb}$

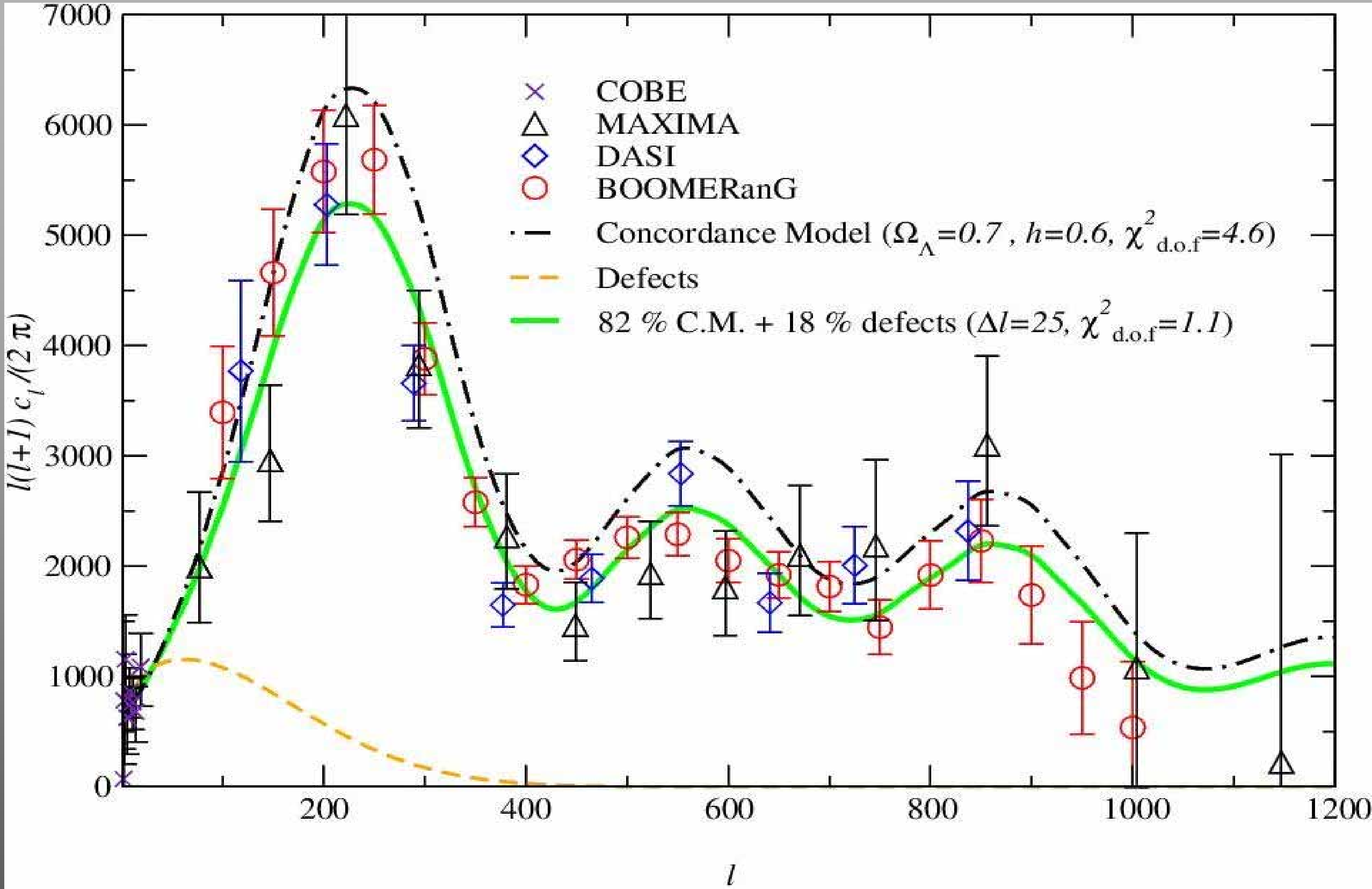
The cosmic string contribution to the CMB temperature anisotropes is highly constrained from the measurements !

$$C_\ell = \lambda C_\ell^{infl} + (1 - \lambda) C_\ell^{cs}$$

Already from the measurements before WMAP, the cosmic string contribution was at the most 18%.

Bouchet, Riazuelo, Peter & Sakellariadou PRD 65, 021301 (2001)

WMAP should impose even strongest constraints.



Bouchet, Riazuelo, Peter & Sakellariadou PRD 65, 021301 (2001)

Bayesian analysis in a 3dim space:

$$C_\ell = \alpha C_\ell^{infl} + \beta C_\ell^{cs}$$

parameters α, β, n_s with ranges:

$$\alpha \in [0.95; 1.05]; \beta \in [0.0; 0.105]; n_s \in [0.955; 1.02]$$

WMAP and SDSS data set un upper bound on the fraction of primordial fluctuations sourced by local cosmic strings, which at 99% confidence is:

$$\beta \leq 0.09$$

Pogosian, Wyman, Wasserman, astro-ph/0403268

2 basic questions :

Which is the energy scale of the formed CS ?

Which is the theoretical predicted CS contribution to the $\delta T/T$?

How does this depend on the parameters of the model…

F-term inflation

Superpotential:

$$W = \kappa S(\Phi_+ \Phi_- - M^2)$$

Scalar potential with radiative corrections:

$$V = \kappa^2 M^4 \left\{ 1 + \frac{\kappa^2 N}{32\pi^2} \left[2 \ln \frac{|S|^2 \kappa^2}{\Lambda^2} + g(z) \right] \right\}$$

$$g(z) = (z+1)^2 \ln(1 + z^{-1}) + (z-1)^2 \ln(1 - z^{-1})$$

$$z = x^2 = |S|^2 / M^2$$

Number of e-folds:

$$N_Q \simeq N(S_Q) = \frac{32\pi^3 M^2}{\kappa^2 N M_{Pl}^2} y_Q^2$$

with

$$y_Q^2 = \int_1^{x_Q^2} \frac{dz}{z f(z)}$$

M_{Pl} : Planck mass

$$x_Q = |S_Q|^2/M^2$$

$$f(z) = (z+1)\ln(1+z^{-1}) + (z-1)\ln(1-z^{-1})$$

The relation between **M** and κ:

$$\frac{M}{M_{Pl}} = \frac{\sqrt{N_Q N}\,\kappa}{\sqrt{32}\,\pi^{3/2} y_Q}$$

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Quadrupole temperature anisotropy:

$$\left\langle\left(\frac{\Delta T}{T}\right)_{Q}^{tot}\right\rangle^2 = \left\langle\left(\frac{\Delta T}{T}\right)_{Q}^{inf}\right\rangle^2 + \left\langle\left(\frac{\Delta T}{T}\right)_{Q}^{cs}\right\rangle^2$$

$$\left\langle\left(\frac{\Delta T}{T}\right)_{Q}^{S}\right\rangle^2 + \left\langle\left(\frac{\Delta T}{T}\right)_{Q}^{T}\right\rangle^2$$

scalar

tensor

Using:

$$\left\langle\left(\frac{\delta T}{T}\right)_{Q-S}\right\rangle^2 = \sqrt{\frac{32\pi}{45}}\,\frac{V^{3/2}}{M_{Pl}^3 V'} \approx \sqrt{\frac{8\pi}{45}}\,\frac{N_Q M^2}{N M_{Pl}^2}\, x_Q^{-1} y_Q^{-1} f^{-1}(x_Q^2)$$

inflation

$$\left\langle\left(\frac{\delta T}{T}\right)_{Q-T}\right\rangle^2 \approx 0.77\frac{V^{1/2}}{M_{Pl}^2} \approx 0.77\,\text{ô}\,\frac{M^2}{M_{Pl}^2}$$

cosmic strings

$$\left\langle\left(\frac{\delta T}{T}\right)_{Q-cs}\right\rangle^2 \approx (9-10)G\mu \approx 18\pi\frac{M^2}{M_{Pl}^2}$$

with $\mu = 2\pi\langle\phi\rangle^2$

and normalizing the total quadrupole temepature anisotropy to the COBE measurements, we obtain: ...

$$(6{:}3 \, â \, 10^{à\,6})^2 = a\frac{ô^2 N N_Q}{32ù^2}a^2 y_Q^{à\,4}$$

$$â \; a\frac{64N_Q}{45N} x_Q^{à\,2} y_Q^{à\,2} f^{\,à\,2}(x_Q^2) + a\frac{0{:}77ô}{ù}a^2 + 324\,a$$

For given values of $ô; N; N_Q$ we solve numerically the above equation and we get x_Q and thus $y_Q; M$

$$N_Q = 60$$

$$N = 1; 3$$

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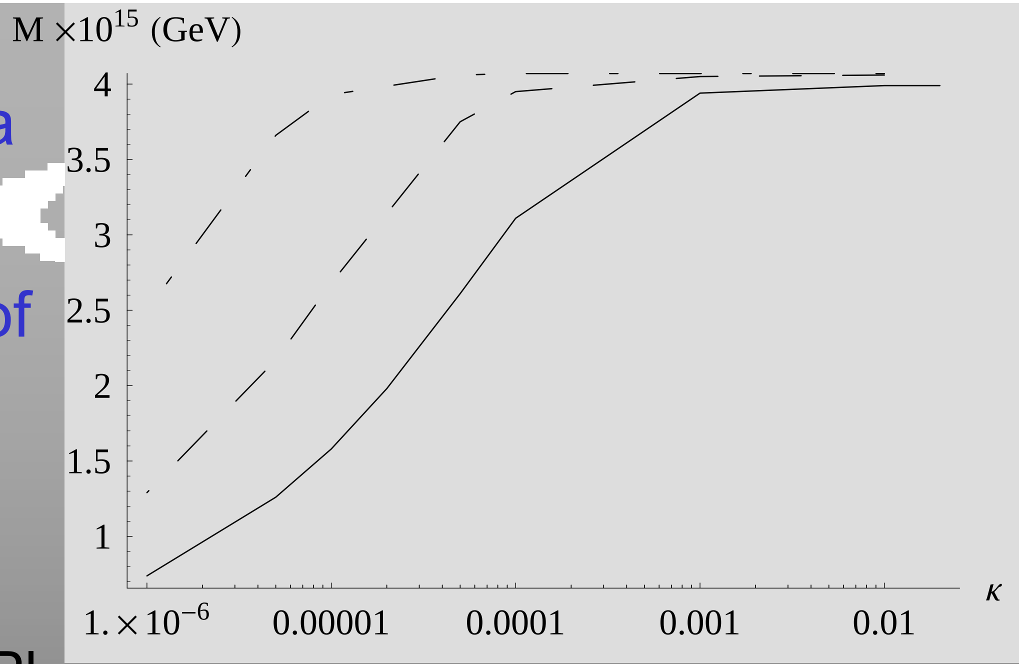
Energy scale of inflation M as a function of the parameter κ .

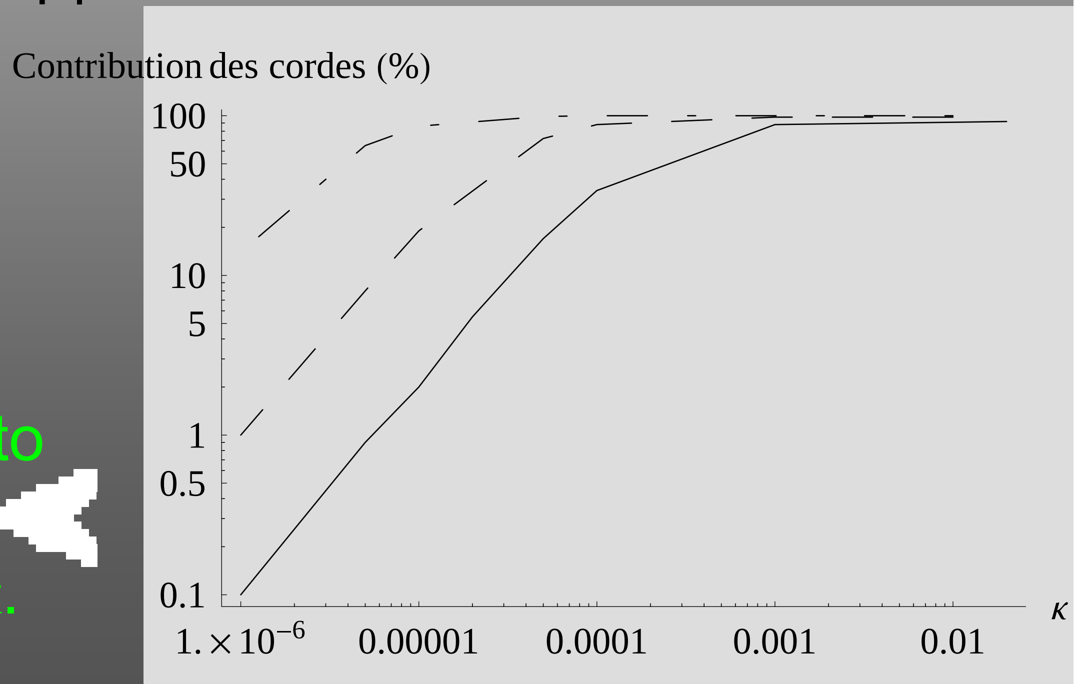


The strings formed at the end of inflation have a mass proportional to the inflationary scale.

M ø O(10^{15})GeV ü M_{Pl}

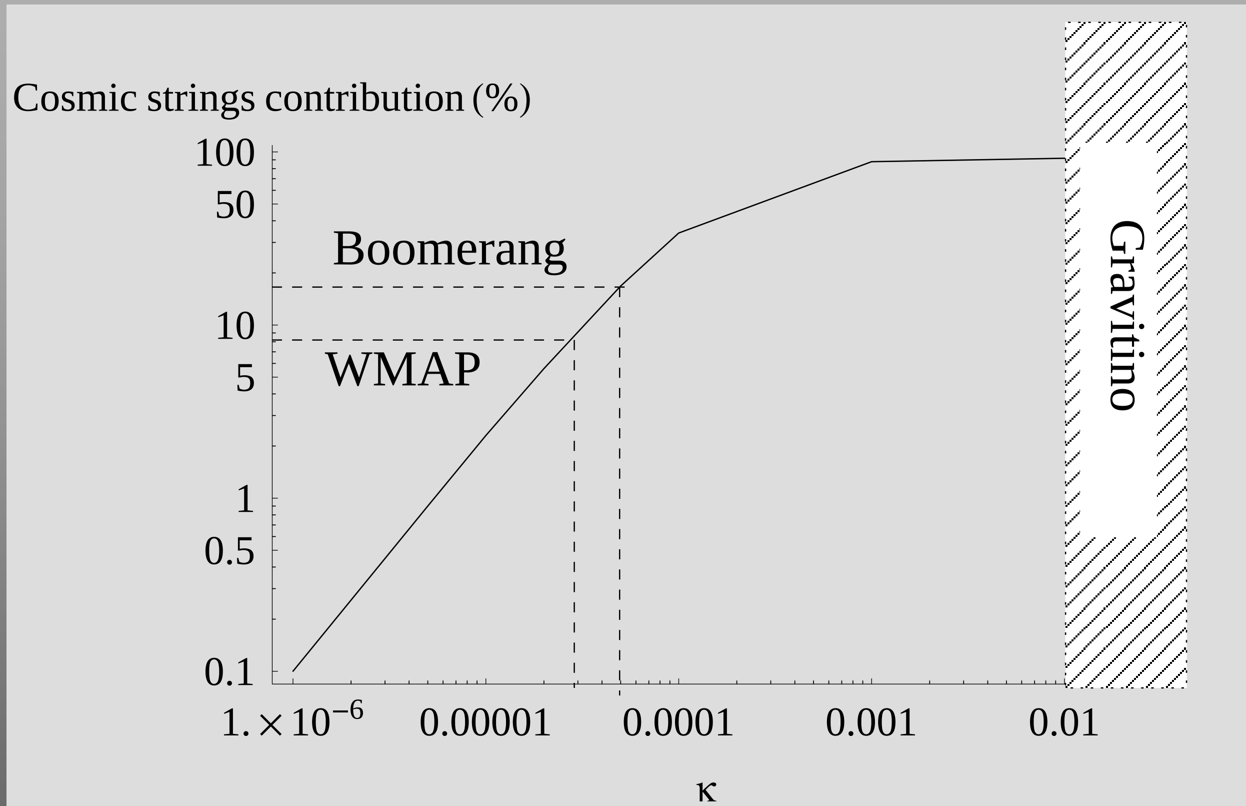
⇨ ~~SUGRA~~

N = 3; 16; 126



Cosmic string contribution to the CMB angular power spectrum as a function of κ.

Constraints on the unique parameter of the model, κ, from cosmological data (i.e., CMB & gravitino)



ô ô (0:8 à 1) â 10à 2

ô ô 3 â 10à 5

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Moriond 2004

The curvaton model

Embedded strings are topologically unstable and in general not dynamically stable either.

↓

Embedded strings can play the role of the curvaton!

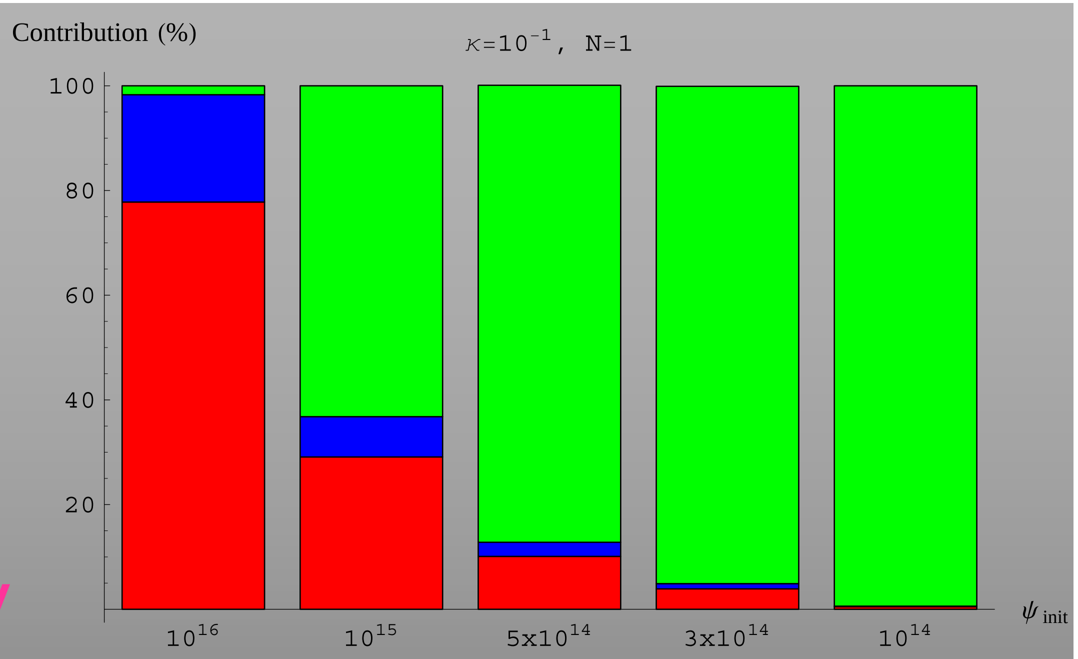
We can increase the allowed value of the parameter κ and still be consistent with the constraints imposed by the CMB measurements.

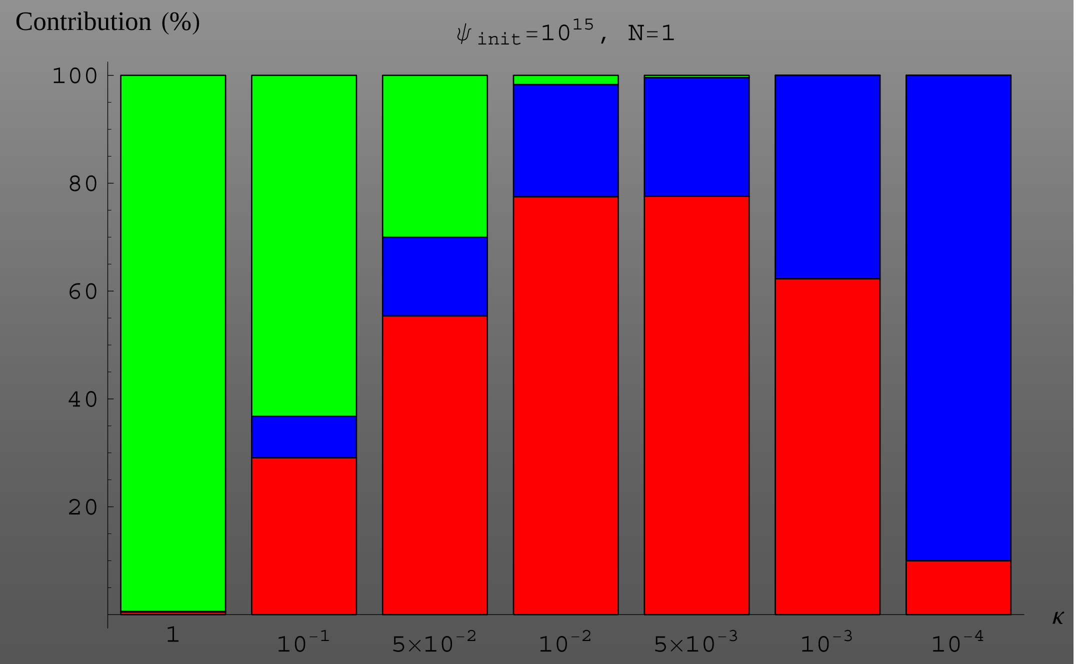
$$\left(\frac{\hat{\imath} T}{T}\right)_{curv}^{2} = \left(à \frac{4\,\hat{\imath}\ {}_{init}}{27\ {}_{init}} \right)^{2}$$

$$= \left(\left(\frac{\hat{o}^{2} N N_{Q}}{32 \grave{u}^{2}}\right)^{2} y_{Q}^{à 4} \left(\frac{32^{2}}{54 â\, 36^{2} \grave{u}^{3}}\right) \hat{O}^{2} \left(\frac{M_{Pl}}{{}_{init}}\right)^{2} \right)$$

Dependence of the various CMB contributions upon the initial value of the curvaton field $_{init}$ and the parameter **κ**.

$_{init}$ ô 3 â 10^{14} $\frac{ô}{10^{à1}}$ GeV





Topological cosmic strings

Inflaton field

Embedded strings (curvaton)

D-term inflation

Requirement : the 9 of an additional U(1) factor with a nonvanishing Fayet-Iliopoulos term

$$W = õ S Ð_+ Ð_à$$

The VEV of $Ð_+ ; Ð_à$ equals the Fayet-Iliopoulos term which also sets the scale of inflation and the energy scale of strings.

This case is much more complicated …

The results in the literature … are WRONG ! …

$$V = \frac{g^2 ø^2}{2}\left[1 + \frac{g^2}{16ù^2}\left[2\ln\frac{|S|^2 õ^2}{Ë^2} + g(z)\right]\right]$$

$$z = x^2 = \frac{õ^2 |S|^2}{g^2 ø}$$

$$\left(\frac{\delta T}{T}\right)_Q^2 ø \left[y_Q^{à 4}\left(\frac{õ^2 N_Q}{16ù^2}\right)^2\left(\frac{16 N_Q}{45}x_Q^{à 2}\, y_Q^{à 2} f^{à 2}(x_Q^2) + \left(\frac{0.77 g}{\sqrt{2ù}}\right)^2 + 324\right)\right]$$

$6{:}3 â 10^{à 6}$

To reach the end of inflation

$$\frac{ø}{õ^2} õ 10^{36}$$

$S_Q ø M_{Pl}$ → SUGRA corrections are needed !

Conclusions

String formation is unavoidable at the end of inflation within SUSY GUTS.

Cosmic string contribution to the CMB data is strongly constrained.

The predicted string contribution depends on the parameters of the inflationary model (F-term / D-term).

↓

We constraint the parameter space.