Networks of Semilocal Strings

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Hybrid Inflation

- E.g. potential

  $V(\varphi, \chi) = \frac{1}{2} m_\varphi^2 \varphi^2 + \frac{1}{2} |\chi|^2 \varphi^2 + \lambda(|\chi|^2 - v^2)^2$,

  where φ inflaton, χ (complex) waterfall field

- SUSY GUT's: e.g. D-term inflation (Dvali, Shafi, Schaefer -94) potential

  $V(S, \Phi_+, \Phi_-) = \kappa^2 S^2 (|\Phi_+|^2 + |\Phi_-|^2) + |\kappa \Phi_+ \Phi_- - \mu^2|^2 + D$-terms,

  where Φ_+, Φ_- charged and S neutral superfield

- Formation of (topologically stable) ANO cosmic strings in the end of inflation

- Add another pair (hypermultiplet) of charged superfields:

  $\Phi_\pm \longrightarrow \Phi_\pm, \widetilde{\Phi}_\pm$
  vacuum manifold is simply connected $\longrightarrow$ no topologically stable strings
  however, **semilocal strings**
  (Urrestilla, Achúcarro, Davis PRL 92 251302, hep-th/0402032)

Further Motivation

Two pairs of charged hypermultiplets naturally arises:

- type II superstrings compactified on Calabi-Yau
  ($N = 2$ SUSY in four dimensions)
- Brane inflation involving $D3/D7$ branes
  (K. Dasgupta, J. Hsu, R. Kallosh, A. Linde, M. Zagermann:
  JHEP 0408:030, hep-th/0405247)

Two hypermultiplet model has the good features of the original (single multiplet) model, especially insensitivity to supergravity corrections.

Semilocal Model

Semilocal strings discovered in the early 90’s
(Vachaspati, Achúcarro -91, Hindmarsh -92)
(reviews: A. & V. : Phys. Rep. 327, 347 2000, H. : Nucl. Phys. B392: 461 -93)

- Abelian Higgs model replaced by SU(2) doublet $\Psi = (\phi, \psi)$
- Lagrangian

  $\mathscr{L} = |(\partial_\mu - iA_\mu)\Psi|^2 \; - \; \frac{1}{4}F_{\mu\nu}F^{\mu\nu} \; - \; \frac{1}{2}\beta(\Psi^\dagger\Psi - 1)^2$
- Scalar to vector mass ratio $\beta = (m_{\text{scalar}}/m_{\text{vector}})^2$
  is the only free parameter.
- $\beta = 1$ Bogomol’nyi bound
- $\beta > 1$ non-linear sigma model: global defects, unstable strings
- $\beta < 1$ stable strings

(for recent discoveries see: Forgács, Reuillon, Volkov: hep-th/0507246)

Semilocal Strings

- Unlike topological strings semilocal occur as open segments: they have ends
- Ends have long-range interactions like global monopoles
- Segments can either contract and disappear or grow to join a nearby segment
- Like topological strings semilocal can reconnect and form loops that contract

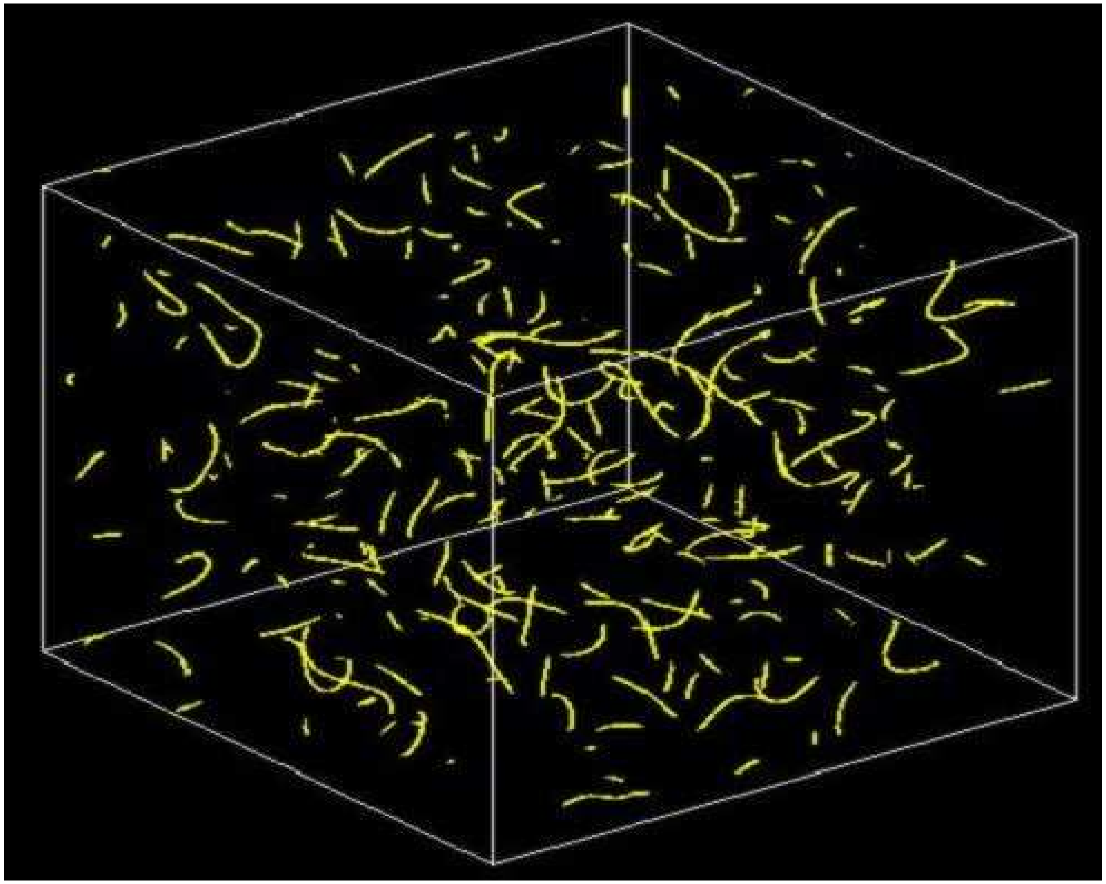
Simulations

- Discretize Lagrangian with the leap frog algorithm and link variables for gauge fields
- Integrate the E.Q.M. in a cubic lattice with periodic boundary conditions ($DX = 1, dt = 0.2$)
- Parallelized code allows studies up to size 512^3 simulation box in a supercluster (COSMOS in Cambridge)
- 10 different initial conditions used for each fixed value of coupling β to achieve good statistics

Earlier numerical studies
(e.g. Achúcarro, Borrill, Liddle -99)

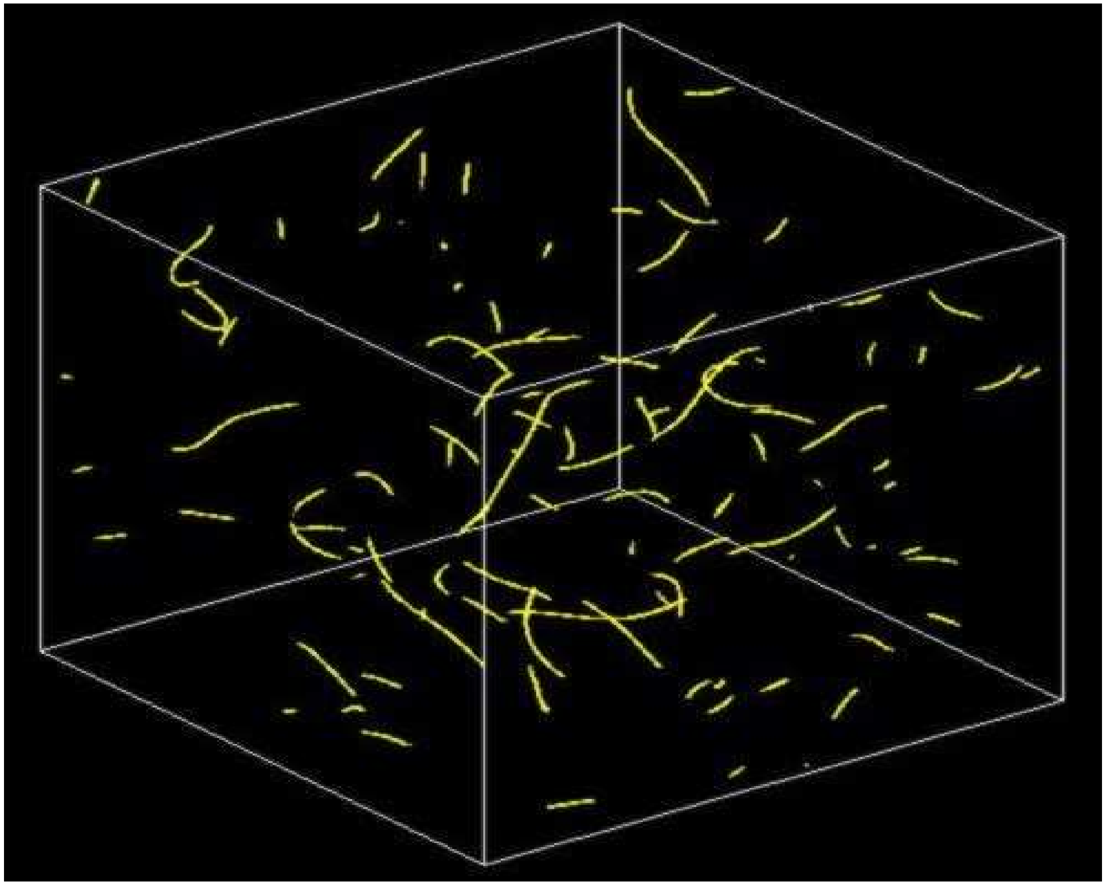
$\beta = 0.36$

time = 150



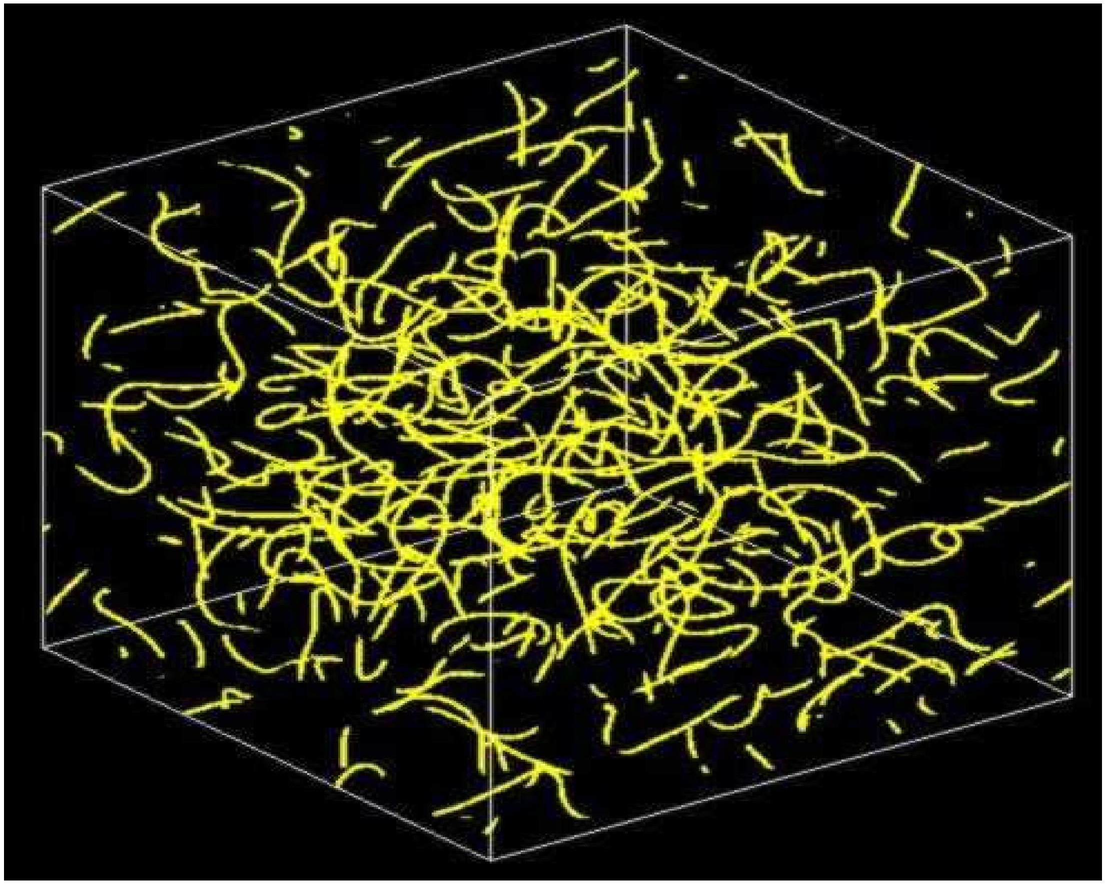
$$\beta = 0.36$$

time = 300



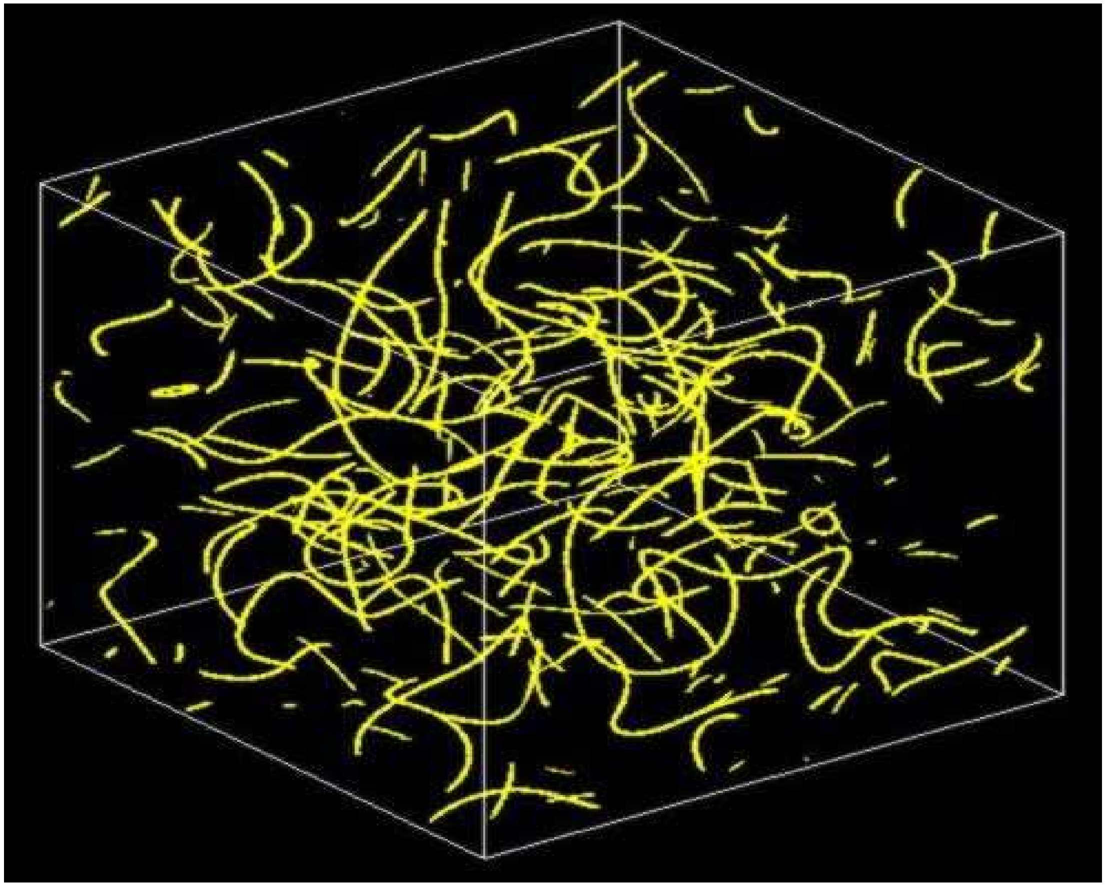
$\beta = 0.04$

time = 150

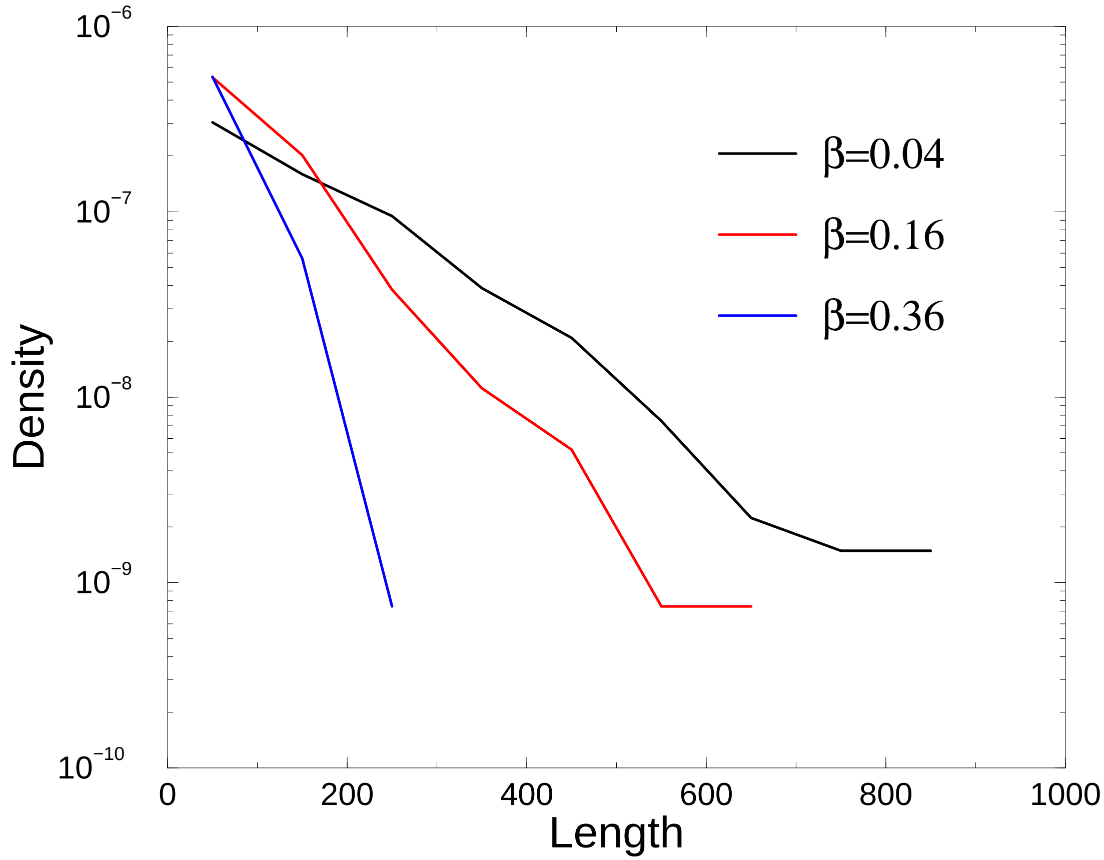


$\beta = 0.04$

time = 300



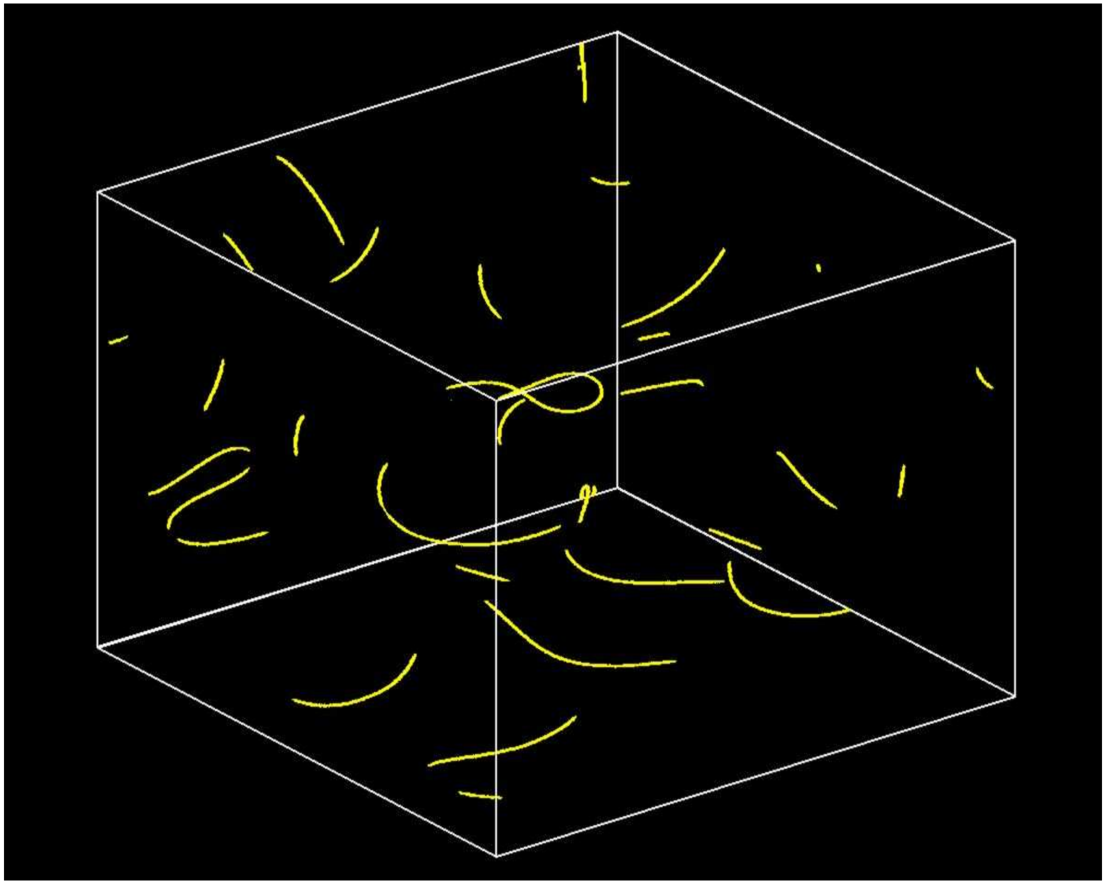
Exponential Length Distribution



That has been predicted for strings ending in monopoles (Everett, Vachaspati, Vilenkin -85).

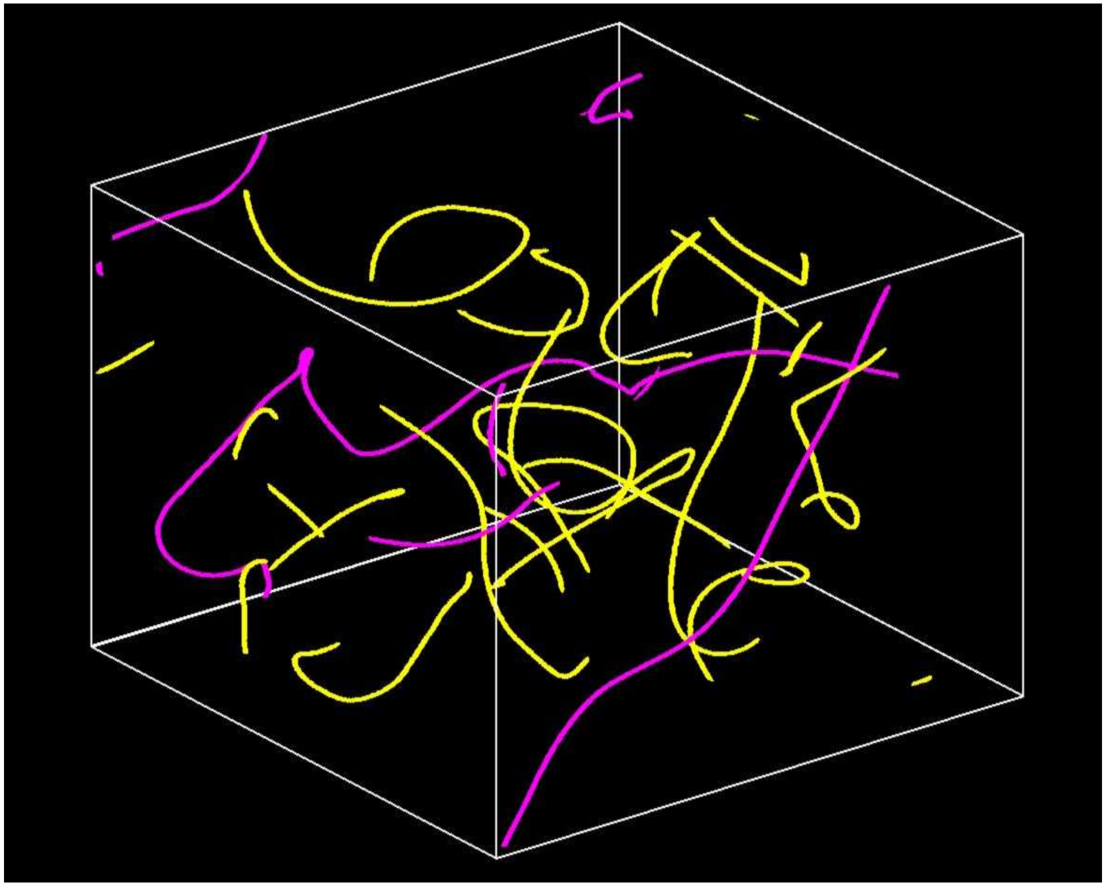
Less Damping

$\beta = 0.36$, damping = 0.05



’Infinite’ Strings

$\beta = 0.04$, damping = 0.05



Conclusions

Formation of the network of semilocal strings was studied

- At the Bogomol'nyi bound the strings disappear
- In the stable regime ($\beta < 1$) length distribution is exponential in the presence of strong damping
- Deep in the stable regime the appearence of 'infinite' semilocal strings when damping is relaxed

Possibility for networks of semilocal strings resembling those of topologically stable ANO's
$\rightarrow$ consequences to CMB signature?

(see M. Hindmarsh's talk in this conference in CMB session on work in progress: Bevis, Hindmarsh, Kunz, Liddle, Urrestilla)