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TOPOLOGICAL STATES OF MATTER

Interpreting Dark Matter only from topological defects:

Part 1: On the global/local topological states in dark matter from nonhomogeneous cosmological models

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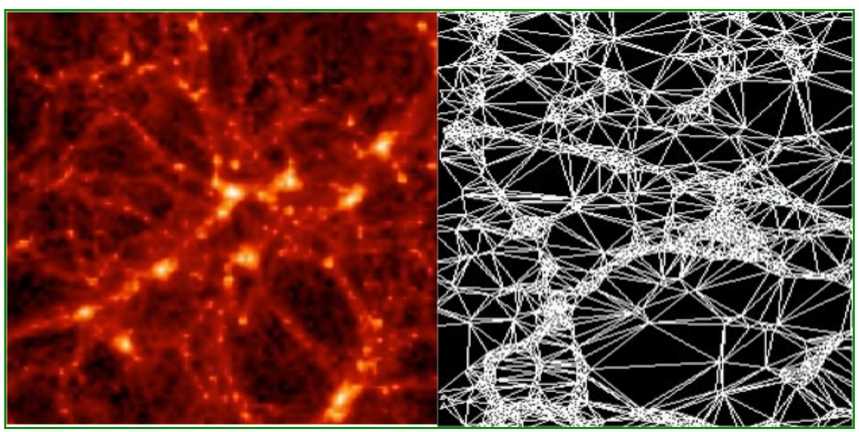

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

FAPESP

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CAPES

Phase transitions and finite temperature field theory

Phase transitions are known to occur in the early universe. Examples we mentioned are the quark to hadron (confinement) transition, which QCD predicts at an energy around 1 GeV, and the electroweak phase transition at about 250 GeV. Within grand unified theories (GUT), aiming to describe the physics beyond the standard model, other phase transitions are predicted to occur at energies of order 10^{15} GeV; during these, the Higgs field tends to fall towards the minima of its potential while the overall temperature of the universe decreases as a consequence of the expansion.

A familiar theory to make a bit more quantitative the above considerations is the $\lambda|\phi|^4$ theory,

$$\mathcal{L} = \frac{1}{2}|\partial_\mu\phi|^2 + \frac{1}{2}m_0^2|\phi|^2 - \frac{\lambda}{4!}|\phi|^4 ,$$

with $m_0^2 > 0$. The second and third terms on the right hand side yield the usual 'Mexican hat' potential for the complex scalar field. For energies much larger than the critical temperature, T_c, the fields are in the so–called 'false' vacuum: a highly symmetric state characterized by a vacuum expectation value $\langle|\phi|\rangle = 0$. But when energies decrease the symmetry is spontaneously broken: a new 'true' vacuum develops and the scalar field rolls down the potential and sits onto one of the degenerate new minima. In this situation the vacuum expectation value becomes $\langle|\phi|\rangle^2 = 6m_0^2/\lambda$.

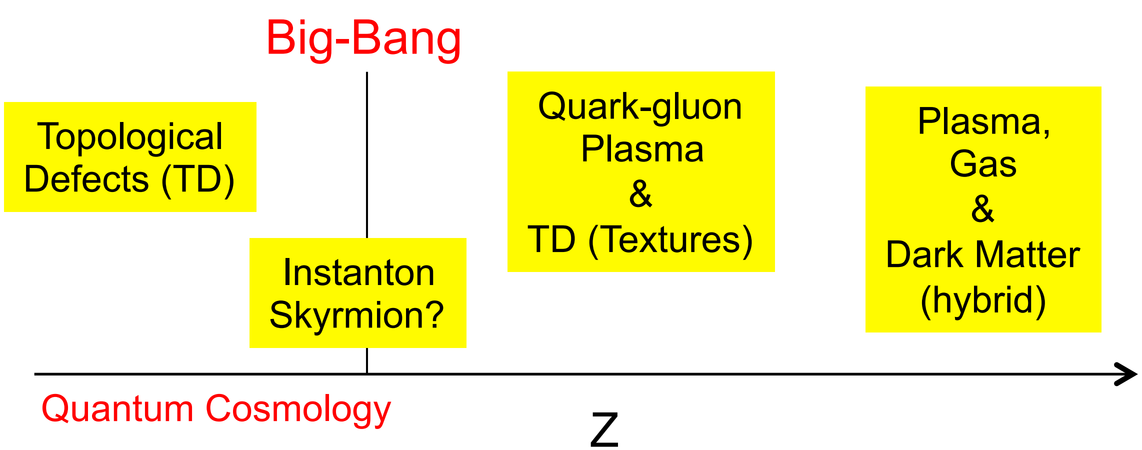
The Kibble mechanism

$$G(r) \simeq \begin{cases} \frac{T_c}{4\pi r}\exp(-\frac{r}{\xi}) & r >> \xi \\ \frac{T^2}{2\pi^2} & r << \xi \ . \end{cases}$$

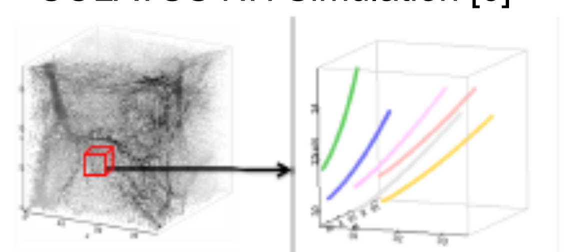
This tells us that domains of size $\xi \sim m^{-1}$ arise where the field ϕ is correlated. On the other hand, well beyond ξ no correlations exist and thus points separated apart by $r >> \xi$ will belong to domains with in principle arbitrarily different orientations of the Higgs field. This in turn leads, after the merging of these domains in a cosmological setting, to the existence of defects, where field configurations fail to match smoothly.

$\pi_0(\mathcal{M}) \neq 1$	$\mathcal{M}$ *disconnected*	DOMAIN WALLS
$\pi_1(\mathcal{M}) \neq 1$	*non contractible loops* in $\mathcal{M}$	COSMIC STRINGS
$\pi_2(\mathcal{M}) \neq 1$	*non contractible 2–spheres* in $\mathcal{M}$	MONOPOLES
$\pi_3(\mathcal{M}) \neq 1$	*non contractible 3–spheres* in $\mathcal{M}$	TEXTURES

Recently a new cosmological scenario called *Cusp Cosmology* [1] has been proposed to explain, in the same scope, the nature of dark energy and dark matter from first geometrical principles. The cusp cosmological projected geometry is described by the generalized equation $x^2+y^2 = (1-z)z^n$ which predicts the existence of a tautochrone of revolution from a primordial instability (PI) localized in a extended pre-big bang space like manifold. Here, we present a first approach on the structure of the PI using the theory of *tachyonic condensation (TC)* [3-5], especially the one proposed by Hwang and Noh [4] which presents a generalized action. Considering a meta stable regime in a vacuum of baryonic matter with ultra high energy density we show that topological defects (string types) can behave as entities that annihilate causing a tachyonic-like condensation (monopole). Given a inhomogeneous metric (ex. Lemaitre-Tolman-Bondi) such structure generates the cusp from which the standard baryonic cosmological space-time emerges rising hybrid topological states of dark matter (textures).



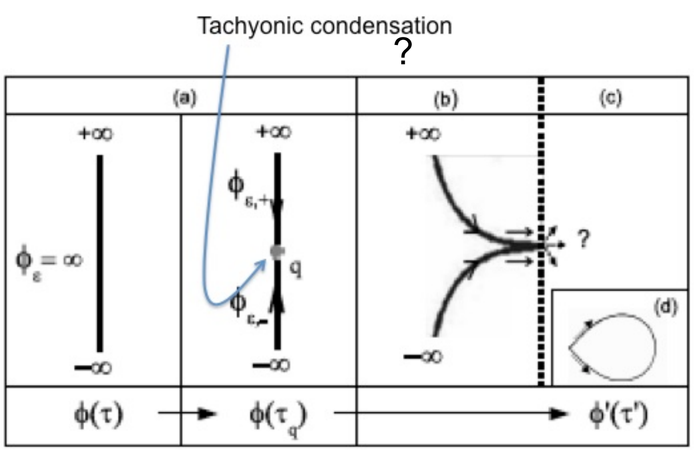
COLATUS NH Simulation [6]

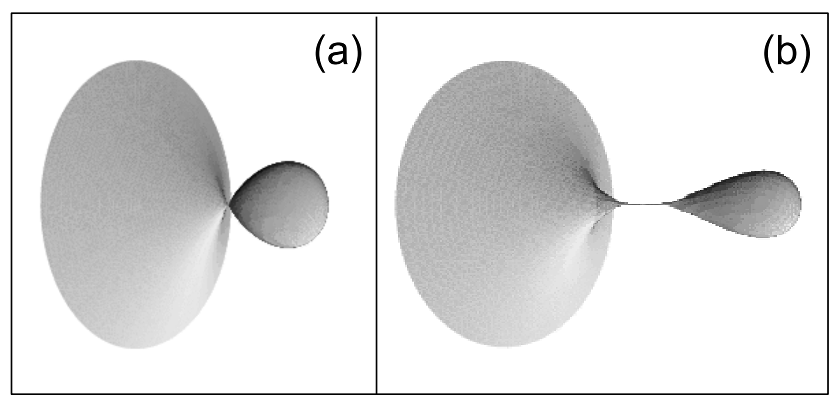


The Global LTB Topology

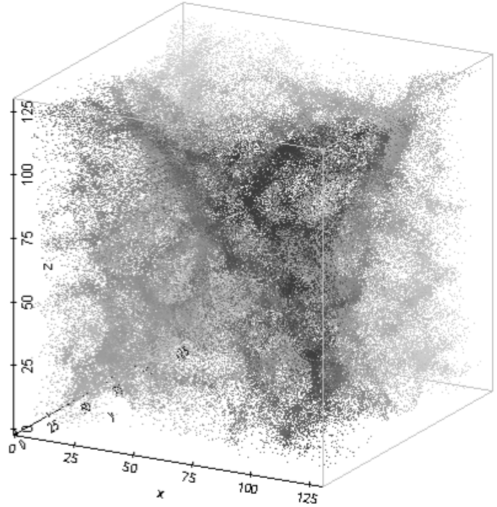
The Friedmann cosmological scenario, represented by the ΛCDM theory, despite being accepted as the standard cosmological model, presents significant theoretical restrictions which are responsible for stimulating the study of alternative models. Despite the Friedmann singularity itself, Dark matter is introduced into the model as additional amount of non-baryonic particles that however interact gravitationally with ordinary matter. Dark energy is introduced into the model as the Cosmological Constant. But there is still no satisfactory physical interpretation for the nature and origin of the parameter Λ. In general, most of the alternative approaches that attempt to explain each of the restrictions listed above does not explain the other. In fact, there are few approaches that deal, consistently, the problems of singularity, dark matter and dark energy in the same theoretical framework. Due to the nature of space-time described by the GTR, a very important aspect of physical cosmology, commonly overlooked, is the fact that an effective theory can also be constructed from first geometric principles. It is based on this property that recently has been introduced an alternative cosmological scenario based on cusp geometries (see Rosa, Strieder and Stalder, [1]). Such formalism begins with the projected geometry drawn through general physical principles, most of them compatible with most cosmologies that admit a 4-dimensional expanding spacetime. We remark that the role of the cusp cosmological scenario is making it easy to assess the geometric nature of the primordial cosmic structure and how the correspondent spacetime evolution might occur considering the existence of an energetic cusp structure instead of infinite singularities (null dimension with infinite density).

However, in the scenario proposed by the cusp geometry the primary instability on an extensive pre-big bang manifold is defined hypothetically without a physical consistent interpretation into the inhomogeneous models that can be used in the construction of the metric and the Lagrangian of the system. Here we interpret the instability as coming from the interaction of topological defects as brane and anti-brane annihilation [2]. As a first approach we apply the generalized action proposed by Hwang and Noh [3] within a metric inhomogeneous LTB type [4].

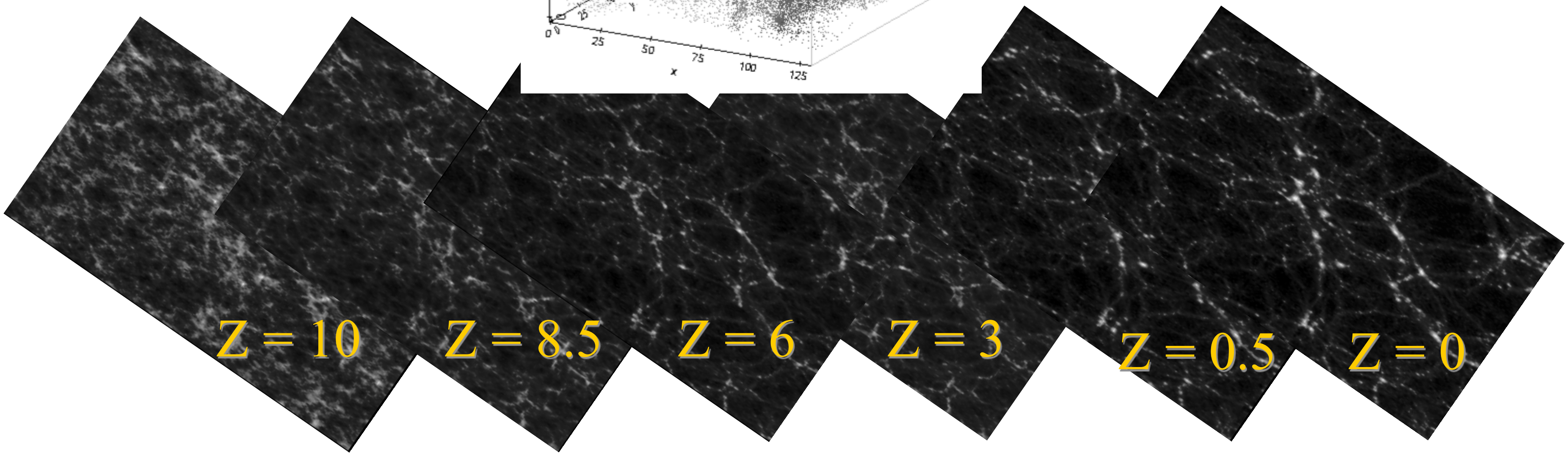


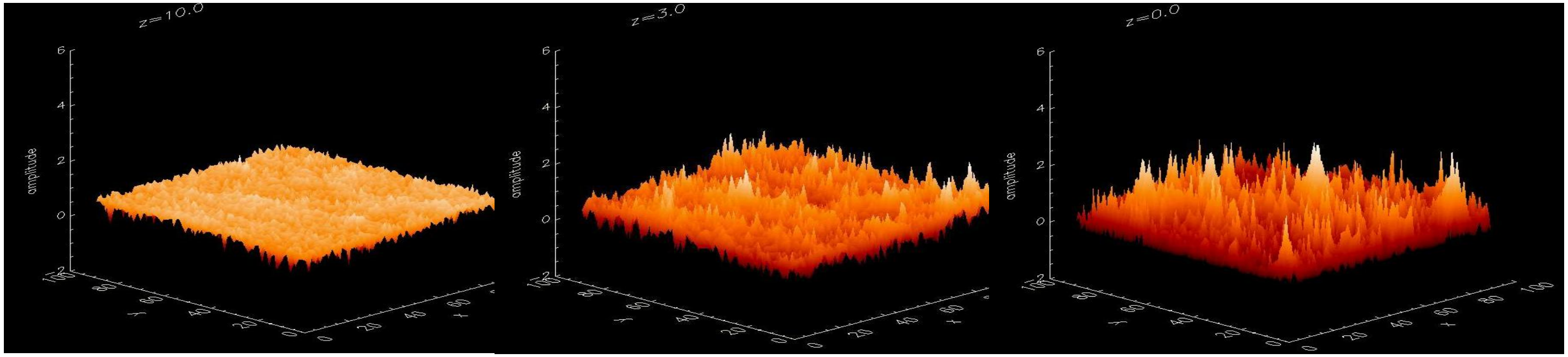


TOPOLOGICAL TEXTURE FORMATION



COLATUS NH Simulation [6]





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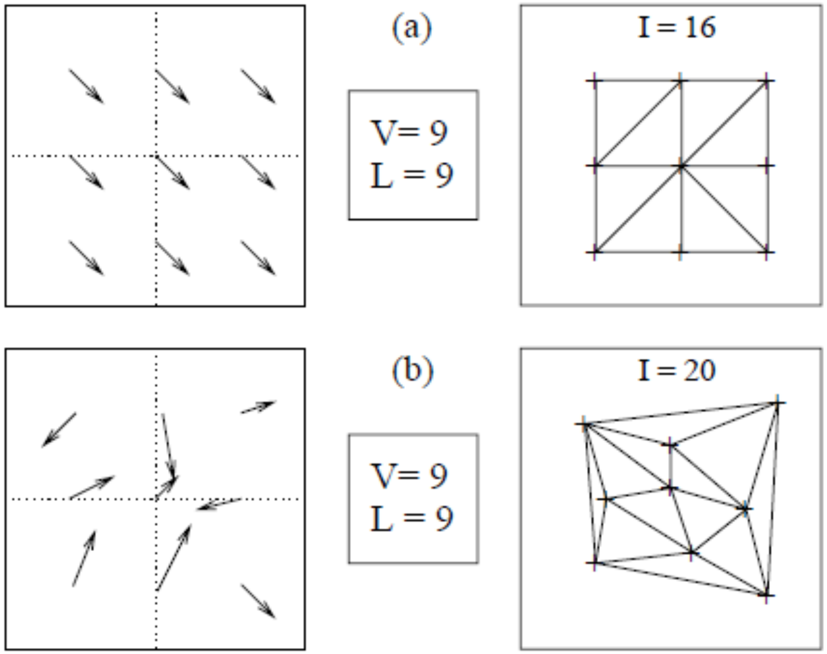
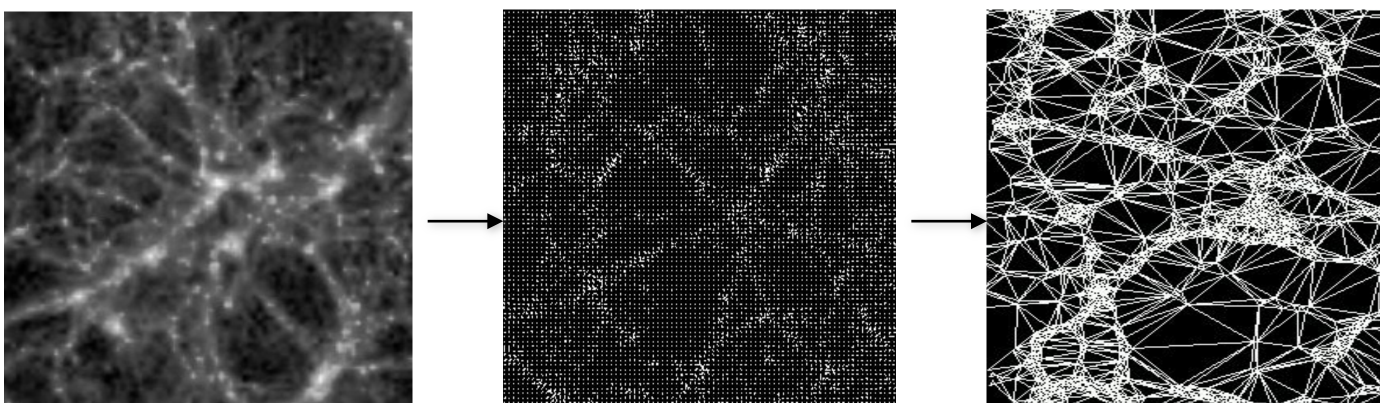


G_A=0.778

89,41-101.20s ➔ Intel Octacore

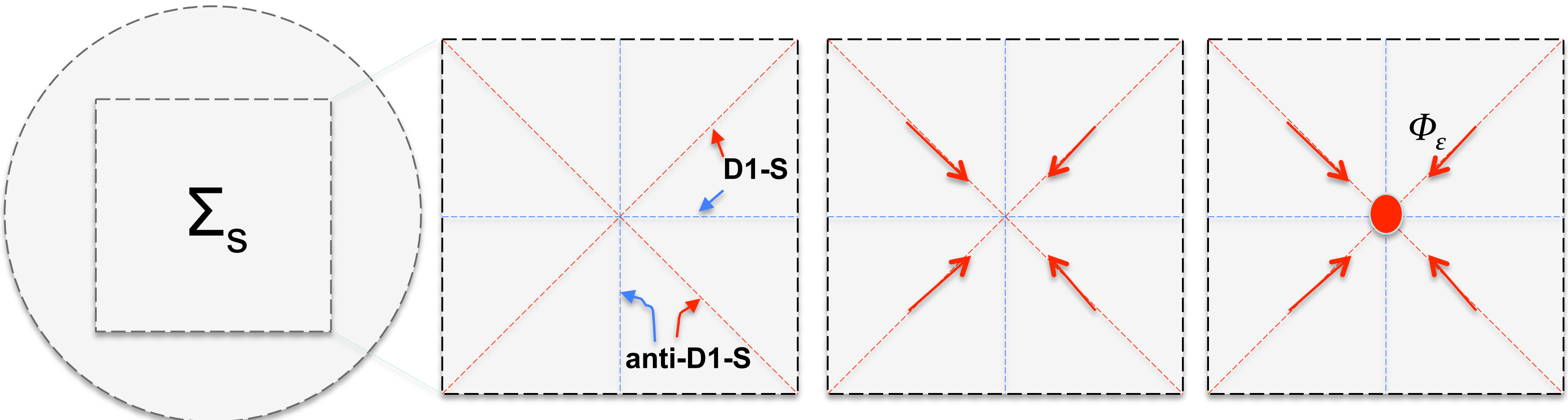
G_A=1.222



G_A= 1.925

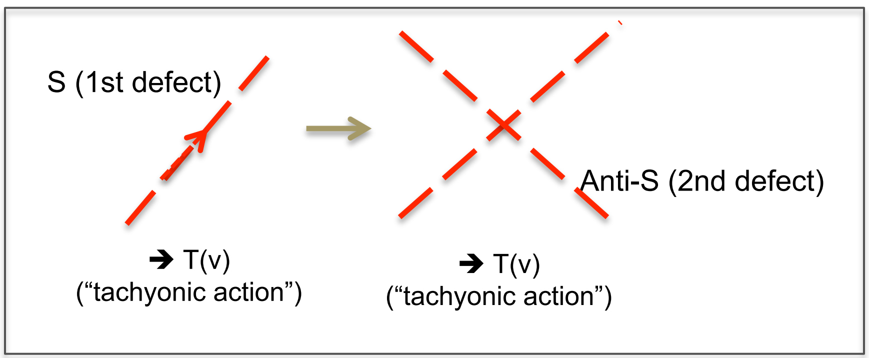
N_V N_C

Representing the tachyonic-like mechanism using a projected geometry (2D)



Hypothetical Space-like/time-like Stable Baryonic Vacuum with ultra-high tachyonic energy density

$(> 3 \times 10^{94} kg/m^3)$



Tachyonic-like Condensation

Where the inflow of energy goes to infinity (baryonic mass = 0) and v ➔ c, then:

$E^2 = p^2c^2$ when v=c

➔ Cusp Starting Point (light-like)

➔ Axisymmetric Spacetime:

$$\boxed{x^2 + y^2 = (1 - z)z^n}$$

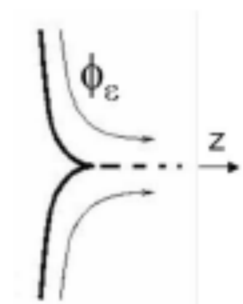
The Flipped Timespace Hypothesis: Σ_s is extended in $(s_1, \tau_1, \tau_2, \tau_3)$ euclidian coordinates.

$\Delta\sigma = [\Delta\tau^2 - \Delta s^2/v^2]^{1/2}$

$$\boxed{\Delta\sigma = \Delta\tau}$$

Hwang-Noh Generalized Action (arXiv:hep-th/0206100v1)

$$S = \int d^4x\sqrt{-g}\left[\frac{1}{2}f(R,\phi,X) + L_m\right]$$



Hwang-Noh
Generalized Action

$$S = \int d^4x\sqrt{-g}\left[\frac{1}{2}f(R,\phi,X) + L_m\right] \quad (1)$$

where $X \equiv \frac{1}{2}\phi^{;c}\phi_{,c}$, and f is a general algebraic function of R, ϕ and X. This action includes the following gravity theories as cases. (1) A minimally coupled scalar field: $f = \frac{1}{8\pi G}R - 2X - 2V(\phi)$. (2) $f(\phi, R)$ gravity: $f = \tilde{f}(\phi, R) - 2\omega(\phi)X - 2V(\phi)$. (3) $p(\phi, X)$ gravity: $f = \frac{1}{8\pi G}R + 2p(\phi, X)$. (4) Tachyonic condensation: $f = \frac{1}{8\pi G}R - 2V(\phi)\sqrt{1+2X}$.

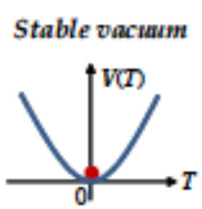
The gravitational field equation and the equation of motion become

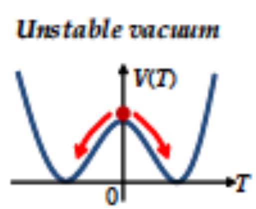
$$G_{ab} = \frac{1}{F}\Big[T^{(m)}_{ab} + \frac{1}{2}(f - FR)\,g_{ab} + F_{,a;b} - F^{;c}{}_{c}g_{ab} - \frac{1}{2}f_{,X}\phi_{,a}\phi_{,b}\Big] \equiv 8\pi G T_{ab}, \quad (2)$$

$$(f_{,X}\phi^{;c})_{;c} = f_{,\phi}, \quad (3)$$

$$T_{(m)a;b}^{\ \ b} = 0, \quad (4)$$

where $F \equiv f_{,R}$. T_{ab} is the effective energy-momentum tensor, and $T^{(m)}_{ab}$ is the energy-momentum tensor of additional matters.





Nonlinear Evolution of the Density Primordial Perturbation

Cusp ➔ nonhomogeneous LTB-like metrics where the "dark matter" effect can be interpreted as spacetime deformation potential (p=0)

$$ds^2 = dt^2 - R'^2\,(1+f(r))^{-1}\,dr^2 - R^2(r,t)d\Omega^2$$

$$f(r) = (dR/dt)^2 - 2m(r)\,R^{-1} - 1/3\,\Lambda\,R^3$$

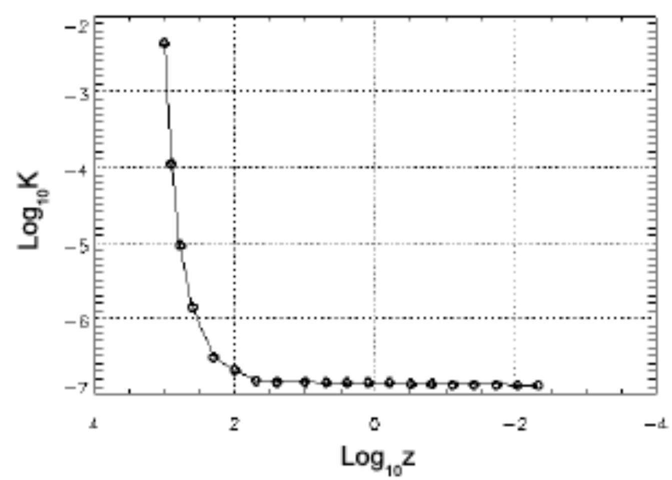
Gaussian Curvature:

$f(r) = -K\,r^2$
$R(r,t) = a(t)\,r$, then

$f(z) = -K(1-z)z^4$

$$K = \frac{n^2}{z^{n/2}}f(n,z).$$

$$K = \frac{16(8 - 24z + 15z^2)}{z^2(8 - 8z + 16z^2 - 40z^3 + 24z^4)^2}$$



CONCLUDING REMARKS

In this preliminary approach on the primordial instability of cusp cosmology [1], as a Kibble-Zurek mechanism [2], we have show that such structure can be interpreted from a Topological State which can be described from a Tachyon condensation-like approach [3,4,5]. Advanced work is required to define the types of topological defects (π-d, Skyrmion?) which are interacting from a spatiotemporal extended domain which admits an exotic switching between space and time whose relativistic effects can be verified in N-body simulations [6]. We believe that this study shows the importance of the cosmological cusp topologies as a system of knowledge where new approaches and physical concepts can be glimpsed beyond the Friedmann singularity [7] taking into account nonhomogeneous cosmology [1-5, 7].

It should be emphasized here that, in order to interpret the dark matter as a topological state (hybrid), most theories of quantum gravity (e.g. quantum loops, dynamical triangulation, etc) may be considered in the structure of the cusp. We are starting work on this approach and it will be presented later.

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