

NONLOCAL STRINGY MODEL of COSMOLOGICAL DARK ENERGY

I. Aref'eva
Steklov Mathematical Institute, Moscow

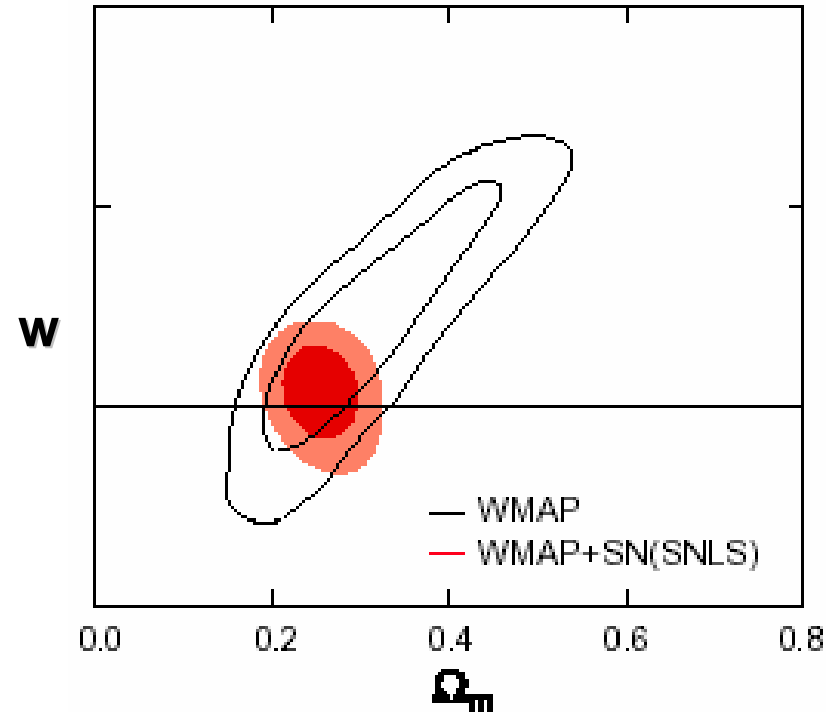
**Bilbao Encounter on New Standard Cosmology,
Bilbao, 10-13 April, 2007**

DE State Parameter.

w < -1 is not from observations

WMAP+SNLS: $w = -0.97^{+0.07}_{-0.09}$

The contours show
68% and 95%
confidence levels for Ω_m and w



WMAP+large-scale structure+SNLS,
no $k=0$ assumption: $w = -1.06^{+0.13}_{-0.08}$

J.Garcia-Bellido, L.Perivolaropoulos today talks; R.Pain tomorrow talk

3 different domains

$w > -1$: “Quintessence”

$w = -1$: Cosmological Constant

$w < -1$: “Phantom”, **break of NEC**

Phenomenological DE Models with $w < -1$

1) Fluid with $w < -1$ “Big Rip” or Doomsday

Caldwell, Kamionkowski,
Weinberg, PRL 2003

2) Ghost scalar field (Phantom) : no “Big Rip”, but instability

3) Lorentz-violating background

4) Modifications of GR

In particular : Brane Cosmology,

S.Odintsov,
more talks here

DGP-model,
instability

This talk: $w < -1$ Universe from string field theory

Universe as slowly decaying D3-brane

I.A., astro-ph/0410443

I.A., L. Joukovkaya, JHEP, 05109(2005)087

I.A., A. Koshelev, JHEP, 07022(2007)041

I.A., A. Koshelev, S. Vernov, PR D72(2005) 064017,

. PL B628(2005)1

G. Calcagni, JHEP, 0605(2006)012

String Field Theory Action for Neveu-Schwarz Tachyon

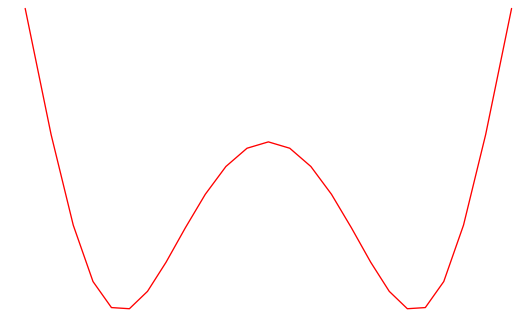
$$S_{string} = \frac{1}{g_4^2} \int d^4x \left(\frac{1}{2} \Phi \left(\xi^2 \frac{\square}{M_s^2} + 1 \right) e^{-\frac{1}{M_s^2} \square} \Phi - \frac{1}{4} \Phi^4 - f \right)$$

$$\frac{1}{g_4^2} = \frac{V_6 M_s^4}{g_o^2} \left(\frac{M_s}{M_c} \right)^6 \Phi \mathbf{F} \left(\frac{\square}{M_s^2} \right) \Phi$$

M_s string scale, g_o string coupling,

M_c compactification scale,

ξ a number dictated by string interaction



Sen's conjecture : $f=1/4$,

I.A, D.Belov,A.Koshelev,P.Medvedev, Nucl.Phys.(2000), Ohmori (2001);

Schnabl, 2005 (bosonic string)

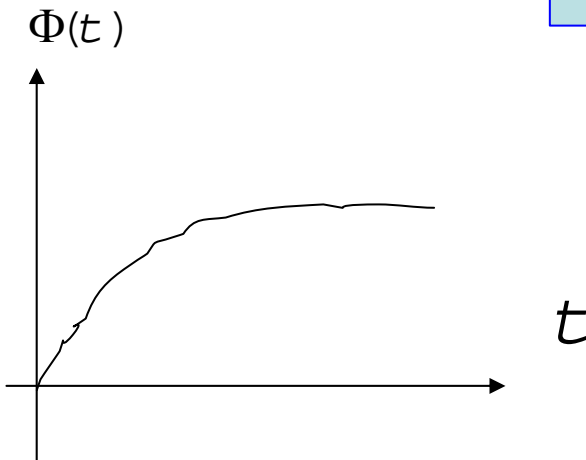
NSR String Field Theory (SFT) Tachyon + Gravity

$$\int d^4x \sqrt{-g} \left(\frac{1}{g_4^2} \left(\frac{1}{2} \Phi F \left(\frac{\square_g}{M_s^2} \right) \Phi - \frac{1}{4} \Phi^4 - f \right) + \frac{M_p^2}{2} R \right)$$

$$F(\mathbf{z}) = (\xi^2 \mathbf{z} + 1) e^{-\mathbf{z}}$$

New conjecture:

$$f = \frac{1}{4} + \Lambda'$$



Effective cosmological constant

I.A., astro-ph/0410443

Nonlocal Models in Cosmology

I. Nonlocality in Matter (*mainly string motivated*)

$$\int d^4x \sqrt{-g} \left(\frac{1}{g_4^2} \left(\frac{1}{2} \Phi F \left(\frac{\square_g}{M_s^2} \right) \Phi - V(\Phi) + \frac{M_p^2}{2} R \right) \right)$$

I.A., astro-ph/0410443,

I.A., L. Joukovkaya, A. Koshelev, S. Vernov:

hep-th/0602015, hep-th/0605085, hep-th/0701184

I.A., I. Volovich, hep-th/0612098, hep-th/0701284

G. Calcagni, hep-th/0512259; N. Barnaby, T. Biswas, J.M. Cline, hep-th/0612230; J. Lidsey, hep-th/0703007

II. Nonlocality in Gravity

$$\int d^4x \sqrt{-g} \left(\frac{1}{g_4^2} \left(\frac{1}{2M_s^2} \Phi \square \Phi - V(\Phi) + \frac{M_p^2}{2} G^{\mu\nu} F \left(\frac{\square}{M}, \dots \right) R_{\mu\nu} \right) \right)$$

T. Biswas..., hep-th/0508194

G. Dvali, ..., hep-th/0703027

Dynamics in the Friedmann metric

$$\Phi(\mathbf{t}) \quad ds^2 = -dt^2 + a^2(t)(dx_1^2 + dx_2^2 + dx_3^2)$$

$$\square_g|_{\text{Friedmann}} = -\partial^2 - 3H(t)\partial$$

E.O.M.:

$$\left(-\xi^2(\partial^2 + 3H\partial) + 1\right) e^{\partial^2 + 3H\partial} \Phi = \Phi^3$$

$$3H^2 = \frac{1}{m_P^2} (\mathcal{E}_p + \mathcal{E}_k)$$

$$m_p^2 = g_4^2 M_p^2 M_s^2$$

**Infinite # of derivatives
(NONLOCALITY)**



**Complicated form of Energy
Momentum tensor** $\mathcal{E}_p, \mathcal{E}_k$

i) Numerical study

$$\mathcal{E}_k = \frac{1}{2} (\xi^2 - K(\Phi)) (\partial e^{\partial^2} \Phi)^2$$

$$K(\Phi) > \xi^2 \longrightarrow w < -1$$

ii) Decomposition on local FIELDS

$$\Phi F\left(\frac{\square_g}{M_s^2}\right)\Phi \sim \sum \varepsilon_n \Psi_n (\square_g - m_n^2) \Psi_n$$

**I.A., I. Volovich, hep-th/0612098;
hep-th/0701284;
I.A., L. Joukovskaya,
S. Vernov, hep-th/0701184;
A. Koshelev
hep-th/0701103, talk here**

Why we get a change of sign?

Flat case

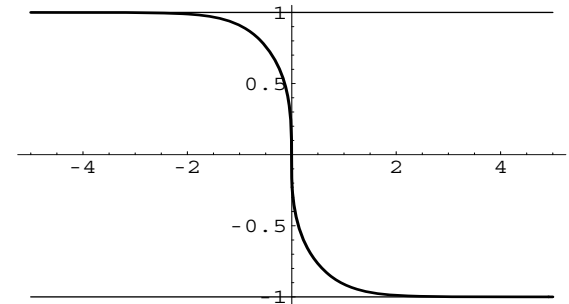
Solution: (kink) **numerically**

$$(-\xi^2 \partial^2 + 1) e^{\partial^2} \Phi = \Phi^3$$



$$\int K(t-t') \Phi(t') dt' = \Phi^3(t)$$

$$\xi^2 < 1$$

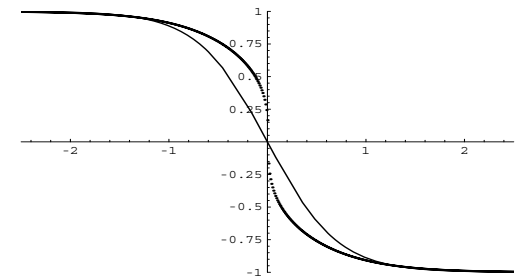


Effective local approximation



Ghost

$$((-\xi^2 + 1)\partial^2 + 1) \Phi = \Phi^3$$



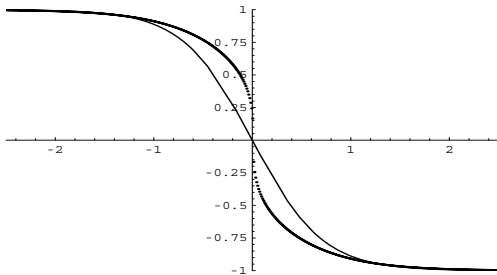
Ya.Volovich(JPA, 2002)+Vladimirov(TMF, 2002)
I.A,Joukovskaya,Koshelev, JHEP, 2002

Exact Solution for Toy Model

$$\ddot{\Phi} + 3H\dot{\Phi} - V'_{\Phi} = 0$$

$$3H^2 = \frac{1}{m_p^2} \left(-\frac{1}{2}\dot{\Phi}^2 + V(\Phi) \right)$$

$$\Phi(t) = \tanh t$$



$$a(t) = a_0 (\cosh t)^{\frac{1}{3m_p^2}} \exp\left(\frac{\cosh^2 t - 1}{12m_p^2 \cosh^2 t}\right)$$

$$V(\Phi) = \frac{1}{4} (1 - \Phi^2)^2 + \frac{1}{12m_p^2} \Phi^2 (3 - \Phi^2)^2$$

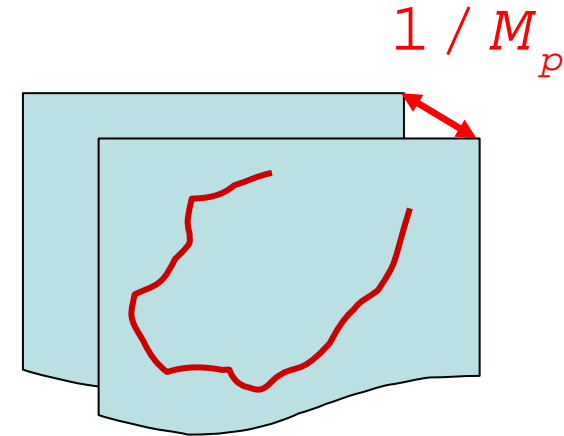
$$H = \frac{1}{3m_p^2}$$

I.A., Koshelev, S. Vernov,
TMF, 2006, PRD, 2005,
S. Vernov, talk here

Hubble Parameter

$$\bar{H} \sim m_p^{-2}$$

$$m_p^2 = \frac{M_p^2}{M_s^2} \frac{g_o^2}{v_6} \left(\frac{M_c}{M_s} \right)^6$$



$$1/M_s$$

$$M_c \sim M_p \quad H \sim M_p \left(\frac{M_s}{M_p} \right)^9$$

$$M_s \sim 10^{-6.6} M_p$$

$$H \sim 10^{-60} M_p$$

M_s – string scale, M_p – Planck scale

SUMMARY:

Universe as D3-brane

String Field Theory Dynamics

$$M_s \sim 10^{-6.6} M_P$$

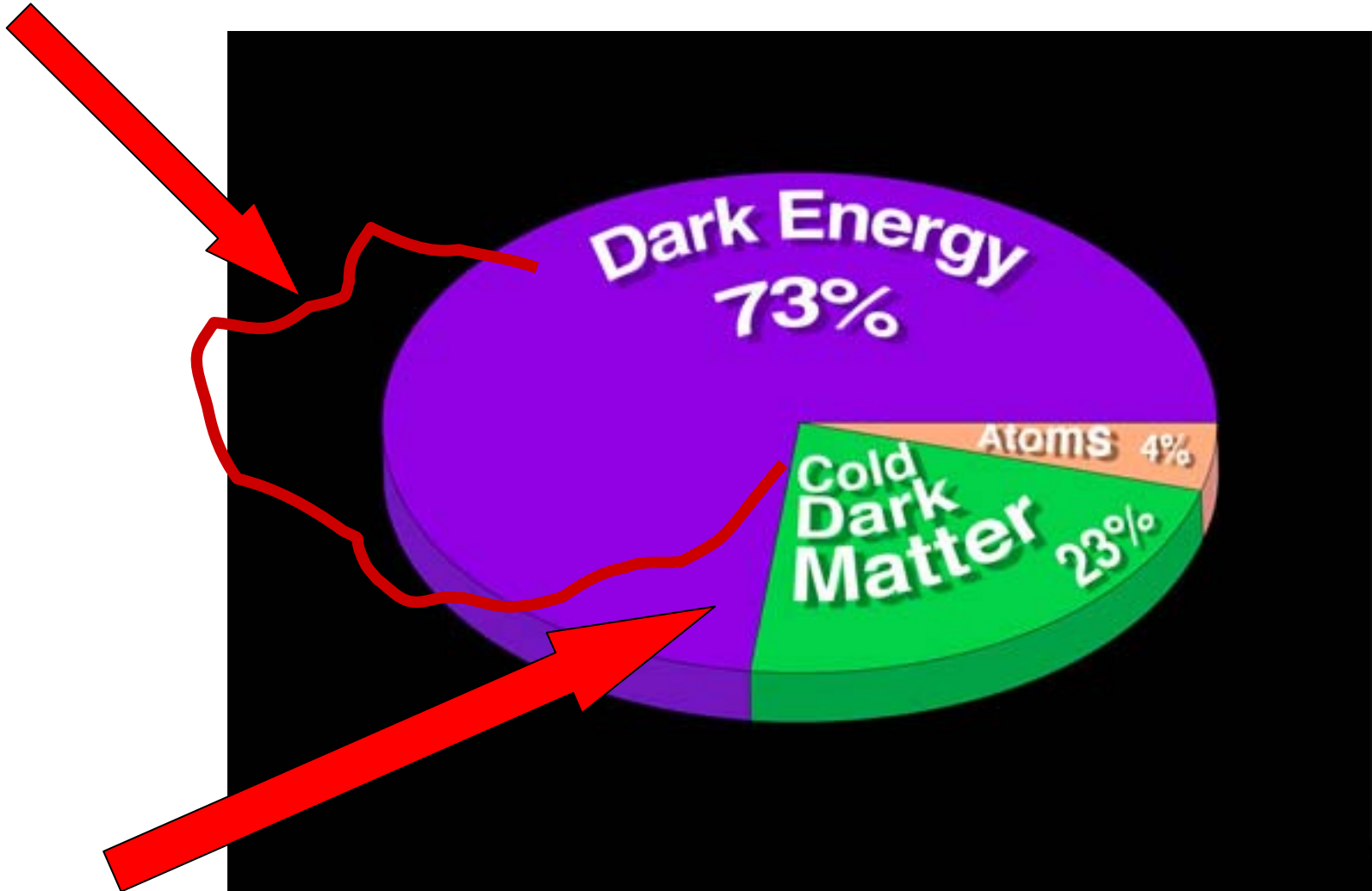
Dark Energy as Open String Tachyon

Hubble Parameter

$$H \sim 10^{-60} M_P$$

Nonlocal String Scalar Field Dynamics: $w < -1$

STRING !!!



D-BRANE !