Fourth Regional Meeting in String Theory
Patras, Greece June 10-17 2007

# Inflationary de Sitter Solutions from String Effective Theories

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**In collaboration with:**

- **Hervé Partouche, hep-th :** 0705.3206 **and hep-th :** 0706.0728,
***[In effective supergravities from Strings]***
- **Nicolaos Toumbas and Jan Troost, hep-th :** 0704.1996
***[In Suprerstrings with broken SUSY]***

## 1. Introduction

**In the framework of superstring compactifications there are always moduli - fields coupled in a very special way to the gravitational and matter sector of the effective $N = 1$ four-dimensional supergravity.**

**The gravitational and the scalar field part of the $N = 1$ effective Lagrangian has the generic form**

$$\mathcal{L} = \sqrt{-\det g}\left[\ \frac{1}{2}R - g^{\mu\nu}\ K_{\imath\bar{\jmath}}\ \partial_\mu\phi_\imath\partial_\nu\bar{\phi}_{\bar{\jmath}}\ - V(\phi_\imath)\ \right]$$

$K_{\imath\bar{\jmath}}$ **is the metric of the scalar manifold**

$V$ **is the scalar potential of the $N = 1$ SUGRA.**

**We will work always in gravitational mass units with**

$$M = \frac{1}{\sqrt{8\pi G_N}} = 2.4 \times 10^{18} GeV.$$

**What will be crucial in this work is the non-triviality of the scalar kinetic terms $K_{\imath\bar{\jmath}} \longrightarrow$ which will provide us with new accelerating cosmological solutions once the**

**i) Radiative**
**and**
**ii) Temperature**

**corrections are taken into account.**

Superstrirg vacua with spontaneously broken supersymmetry and consistent at the classical level with a flat space-time define a very large class of "no-scale" supergravity models.

Among them, a class of potential candidates exist which extend in low energies the physics of the standard model at O(1) TeV energy scale.

This class of models contains an enormous number of consistent string vacua, that are constructed via freely acting orbifolds, "geometrical fluxes", in Heterotic or Type IIA,B orientifold compactification, or in type IIA or IIB compactification, with geometrical or non-geometrical fluxes RR-fluxes or else.

- **Generalization of the Scherk–Schwarz gauging to superstring theory.**

**Rohm, 84; Kounnas, Porrati, 88**
**Ferrara, Kounnas, Porrati, Zwirner, 89**
**Kounnas, Rostand, 90**
**Kiritsis, Kounnas, Petropoulos, Rizos, 99**
**Antoniadis, Dudas, Sagnotti, 99**
**Antoniadis, Derendinger, Kounnas, 99**
**Derendinger, Kounnas, Petropoulos, Zwirner, 04**
**Derendinger, Kounnas, Petropoulos, 05,06,**

- **Simultaneous presence of NS, RR $H^3$, $F^3$.**

**Frey, Polchinski, 02**
**Giddings, Kachru, Polchinski, 02**
**Kachru, Schulz, Trivedi, 03**
**Kachru, Schulz, Tripathy, Trivedi, 03**
**Derendinger, Kounnas, Petropoulos, Zwirner,04, . . .**

**Thanks to the supersymmetric "no-scale" structure, and despite the plethora of this type of string vacua, an interesting universal scaling property emerges, that we will try to explore in this work.**

**Namely, we will study in more detail, the non-trivial cosmological implications due to the existence (at the classical level) of some special moduli fields.**

**One of these special moduli, $\Phi$, is the super-partner of the Goldstino. It defines the field-dependence of the gravitino mass-term :**

$$m(\Phi) = C \ e^{\alpha\Phi},$$

**and couples to the trace of the energy momentum tensor of a sub-sector of the theory.**

**Other special moduli are those with non-trivial $\Phi$-dependent kinetic terms. These moduli appear naturally in all string compactifications.**

**In order to be more explicit let us consider as example the type IIB orientifold with $D_3$-branes and non-trivial NS and RR three form fluxes $H^3$ and $F^3$.**

**Due to the presence of non trivial fluxes, a well known superpotential $W(S, U_A)$ is induced that stabilizes the complex structure moduli $U_A$ and the coupling constant modulus $S$.**

**The remaining $h_{1,1}$ - moduli $T_A$ are still flat directions at the classical level.**

**The Kälher potential is also well known and is given by the intersection numbers $d_{abc}$ of the Calabi-Yau manifold:**

$$K = -\log \; d_{abc}(T_a + \bar{T}_a)(T_b + \bar{T}_b)(T_c + \bar{T}_c)$$

**The superpotental $W$ is constant.**

**The potential of the effective $N = 1$ "no-scale" supergravity is identically zero with a non-trivial gravitino mass**

$$m^2 = |W|^2 e^K$$

**This generic "no-scale" structure emerges in all type IIB orientifold compactifications with fluxes.**

**Keeping for simplicity the direction $T_a = \gamma_a T$ and freezing all other directions the Kälher potential take the well known $SU(1,1)$ form**

$$K = -3\log(T + \bar{T})$$

**giving rise to kinetic term and gravitino mass term**

$$g_{\mu\nu}\ 3\frac{\partial_\mu T \partial_\nu \bar{T}}{(T+\bar{T})^2}, \qquad m^2 = C\, e^K = \frac{C}{(T+\bar{T})^3}$$

**Freezing further the Im$T$ and defining the field $\Phi$:**

$$e^{2\alpha\Phi} = m^2 = \frac{c}{(T+\bar{T})^3}$$

$$g_{\mu\nu}\ 3\frac{\partial_\mu T \partial_\nu \bar{T}}{(T+\bar{T})^2} = g_{\mu\nu}\ \frac{\alpha^2}{3}\ \partial_\mu \Phi \partial_\nu \Phi\ .$$

**The choice $\alpha^2 = 3/2$ normalize canonically the kinetic terms of the modulus $\Phi$.**

**The other extra moduli we will consider here are those with kinetic terms that scale with the inverse volume of the $T$-moduli :**

$$K_s = g_{\mu\nu}\, c_s\, \frac{\partial_\mu \Phi_s \partial_\nu \Phi_s}{(T+\bar{T})^3} = g_{\mu\nu}\, \frac{1}{2}\, e^{2\alpha\Phi}\, \partial_\mu \Phi_s \partial_\nu \Phi_s$$

**Moduli with this scaling property appear in *a very large class of string compactifications.***

**i) All moduli fields leaving in the parallel space of $D_3$-branes.**
**ii) All moduli coming from the twisted sectors in $Z_3$ - orbifold compactifications in heterotic string. (After the non-perturbative stabilization of $S$ due to gaugino condensation and flux-corrections.)** **Kounnas Porrati, 87**

**Ferrara Kounnas Porrati, 87**

**Derendinger, Kounnas, Petropoulos, 05, 06, ...**

## 2. Gravitational, Moduli and Thermal Equations

**Consider the system of the moduli fields $\Phi, \Phi_s$, taken together with all other relevant degrees of freedom of the theory which can be parameterized by an effective pressure $P(T)$ and energy density $\rho(T)$.**

**We are interested for the gravitational solutions that are based on isotropic and homogeneous FRW space time metrics:**

$$ds^2 = -dt^2 + a(t)^2 d\Omega_3^2.$$

**$\Omega_3$ denotes a 3-dimensional closed space with constant curvature $k$, e.g 3-dimensional sphere.**

**The two independent gravitational equations of the system are:**

**i) The "Hubble" equation**

$$3H^2 = -\frac{3k}{a^2} + \rho(T) + \frac{1}{2}\dot{\Phi}^2 + \frac{1}{2}\, e^{2\alpha\Phi}\dot{\Phi}_s^2 + V(\Phi), \quad H = \left(\frac{\dot{a}}{a}\right)$$

**ii) The equation of the variation with respect to the scale factor $a$, modulo the "Hubble" equation:**

$$\dot{H} + 3H^2 = -\frac{2k}{a^2} + \frac{1}{2}(\rho - P) + V + \frac{1}{2}\, a\frac{\partial V}{\partial a}$$

***** In the literature the term $a\,\frac{\partial V}{\partial a}$ is frequently neglected.**

**This term will play a crucial role in the derivation of the inflationary solutions under investigation.**

**The moduli field equations:**

$$\ddot{\Phi} + 3H\dot{\Phi} + \frac{\partial}{\partial \Phi}\left(V - P - \frac{1}{2}\, e^{2\alpha\Phi}\dot{\Phi}_s^2\right) = 0$$

$$\ddot{\Phi}_s + \left(3H + 2\alpha\dot{\Phi}\right)\, \dot{\Phi}_s = 0$$

**The $\Phi_s$ equation can be solved immediately**

$$K_s \;\equiv\; \frac{1}{2}\, e^{2\alpha\Phi}\dot{\Phi}_s^2 \;=\; c_s\, \frac{e^{-2\alpha\Phi}}{a^6}$$

**The total energy conservation of the system is the remaining independent equation of the system**

$$\frac{d}{dt}\left(\rho + \frac{1}{2}\dot{\Phi}^2 + K_s + V(\Phi)\right)$$

$$+3H\left(\rho + P + \dot{\Phi}^2 + 2K_s\right) = 0.$$

**Some useful relations that are valid for the thermal quantities $\rho(T)$ and $P(T)$:**

**i) The entropy equation**

$$T\,\frac{\partial\,P}{\partial T} = \rho + P$$

**ii) Scaling equations**

$$\left(m_i\frac{\partial}{\partial m_i} + T\frac{\partial}{\partial T}\right) P \equiv 4P, \quad \left(m_i\frac{\partial}{\partial m_i} + T\frac{\partial}{\partial T}\right) \rho \equiv 4\rho$$

**i) and ii) imply:**

$$m_i\frac{\partial}{\partial m_i}\,P = -\,(\rho - 3P).$$

**In the special case of $\Phi$-dependent masses,**

$$m_i = \; C_i \; e^{\alpha \Phi},$$

**we obtain a very fundamental equation involving the modulus field $\Phi$,**

$$-\frac{\partial \; P}{\partial \Phi} \; = \; \alpha \; (\rho - 3P)$$

**The above equation shows clearly that $\Phi$ couples to the (sub-)trace of the energy momentum tensor of the thermal system $\rho, P$.**

## 3) Radiative and the Thermal Corrections

**To proceed further, it is necessary to analyze the structure of the scalar potential $V$ and the thermal functions $\rho, P$. More precisely, we had to specify their dependence on $\Phi, T, a$.**

**Although this analysis looks hopeless in a generic field theory, it is perfectly under control in string effective no-scale supegravity theories.**

**Classically, the potential $V$ is zero along the moduli directions $\Phi$ and $\Phi_s$.**

**At the quantum level $V$ receives radiative and thermal corrections that are given in terms of the effective potential $V(\Phi, a; m_i)$ and in terms of the thermal function $-P(\Phi, T; m_i)$.**

## i) Effective Potential

$$V = V_0 + \frac{1}{64\pi^2}\,\mathrm{Str}\mathcal{M}^0\,\Lambda^4 \log\frac{\Lambda^2}{\mu^2}$$

$$+\frac{1}{32\pi^2}\,\mathrm{Str}\mathcal{M}^2\,\Lambda^2 + \frac{1}{64\pi^2}\,\mathrm{Str}\mathcal{M}^4\,\log\frac{\mathcal{M}^2}{\mu^2} + \ldots$$

**$\Lambda$ is an ultraviolet cut-off**

**$\mu$ stands for the renormalization scale**

$$\mathrm{Str}\mathcal{M}^n \equiv \sum_i (-)^{2J_i}(2J_i + 1)\; m_i^n$$

**Weighted sum over the field-dependent masses $m_i$, and the spin-statistic of particles $J_i$.**

**$V_0 \equiv 0$ in "no-scale" supergravity.**

$$\mathrm{Str}\mathcal{M}^0 = (n_B - n_F) \equiv 0$$

**The $\Lambda^4$ term is absent in SUSY theories.**

**The $\Lambda^2$ term is always proportional to the gravitino mass-term $m(\Phi)^2$**

$$\mathrm{Str}\mathcal{M}^2 = C_2 \; m(\Phi)^2$$

$C_2$ **is a field independent number. It depends only on the geometry of the kinetic terms but not on the details of the superpotential.**

**The $\mathrm{Str}\mathcal{M}^4$ term has logarithmic $\mu$ infrared behavior.**

**In the infrared regularization method adapted in string theory, the scale $\mu^2$ turns out to be proportional to the curvature of the three dimensional space.**

$$\mu = \frac{1}{\gamma a}$$

**The numerical coefficient $\gamma$ is chosen according to the Renormalization Group Equation arguments.**

**Another choice for the infrared scale $\mu$ would be the temperature scale, $\mu = \eta T$.**

**Both choices are physically equivalent. The curvature choice looks more natural and has the advantage to be valid even in the absence of the thermal bath.**

**The $\mathrm{Str}\mathcal{M}^4$ can be expanded in powers of gravitino mass $m(\Phi)$**

$$\frac{1}{64\pi^2}\mathrm{Str}\mathcal{M}^4 = C_4\ m^4 + C_2 m^2 + C_0$$

**Including the logarithmic terms and the contribution from $\mathrm{Str}\mathcal{M}^2$, the total effective potential is organized in powers of $m(\Phi)$:**

$$V = V_4(\Phi, a) + V_2(\Phi, a) + V_0(\Phi, a)$$

$$V_n(\Phi, a) = m^n(\Phi)\,[\ C_n + Q_n\ \log\left(m(\Phi)\gamma a\right)]$$

$$V_n' \equiv \frac{\partial V_n(\phi, a)}{\partial \Phi} = \alpha(\ nV_n +\ m^n Q_n),$$

$$a\frac{\partial V_n(\phi, a)}{\partial a} = \alpha\ m^n Q_n.$$

## ii) Thermal Potential

**At finite temperature the effective potential receives extra contributions from the thermal fluctuations of the bosonic and fermionic states**

$$V_{\rm Total} = V(\Phi, a; m_i) \; - \; P(T, m_i)$$

**The general expressions of the energy density** $\rho(T)$ **and pressure** $P(T)$ **are**

$$\rho(T) = \sum_i \; T^4 f_\rho\left(\frac{m_i}{T}\right) \qquad P(T) = \sum_i \; T^4 f_P\left(\frac{m_i}{T}\right)$$

**For massless degrees of freedom,**

$$\rho = 3P = \frac{\pi^4}{15}\left(n_B + \frac{7}{8} n_F\right) T^4 \, .$$

**There are three distinct sub-sectors of states:**

$i)$ **A sub-sector of massless states with.**

$$\rho - 3P = 0 \quad \longrightarrow \quad \partial P / \partial \phi = 0$$

$ii)$ **A sub-sector of states with non vanishing masses *independent* of** $m(\Phi) \rightarrow \partial P / \partial \phi = 0$

• **If** $m_i$ **is below** $T$

$$P(T) = P(T, m_i = 0) + m_i \frac{\partial P}{\partial m_i} = c_p \, T^4 - \Sigma \, c_i \, m_i^2 \, T^2$$

• **If** $m_i$ **is above** $T$**, then the contribution of the particular degrees of freedom is exponentially suppressed and decouples from the thermal system.**

$iii)$ **A sub-sector with non vanishing masses *proportional to* $m(\Phi)$.**

$$\frac{\partial P}{\partial \Phi} = -\alpha(\rho - 3P)\,.$$

**According to the scaling with respect to $T$ and $m(\Phi)$, we can separate**

$$\rho = \rho_4 \;+\; \rho_2\,, \qquad\qquad P = P_4 \;+\; P_2\,,$$

$$\left( m(\Phi)\,\frac{\partial}{\partial m(\Phi)} \;+\; T\,\frac{\partial}{\partial T} \right)\,(\rho_n,\;P_n) = n\,(\rho_n,\;P_n)\,.$$

$\rho_4$**,** $P_4$ **receive contributions from themassless states of the** $i)$**-sector, the** $T^4$ **part of the** $ii)$**-sector and from all states of the** $iii)$**-sector.**

$$\rho_4 = T^4 \left( \frac{\pi^4}{8}\; n^* + \sum_i f_\rho \left( \frac{m_i(\Phi)}{T} \right) \right)$$

$$P_4 = T^4 \left( \frac{\pi^4}{24}\; n^* + \sum_i f_P \left( \frac{m_i(\Phi)}{T} \right) \right)$$

**$\rho_2$ and $P_2$ arise from the $T^2$ part of $\rho$, $P$ of the $ii)$-sector:**

$$\rho_2 = P_2 = -\sum c_i\; m_i^2\; T^2 \;\equiv\; -\, M^2\; T^2\,.$$

## 4) Critical Solution

**The fundamental ingredients in our analysis are the scaling properties of the total effective potential at finite temperature.**

**Independently of the complication appearing in the radiative and temperature corrected effective potential the scaling violating terms are under control. Their structure suggests to search for a solution where all the scales of the system $m(\Phi)$, $T$ and $\mu = (1/\gamma a)$ have similar evolution in time.**

$$m(\Phi) = \frac{1}{\gamma a} \quad \rightarrow \quad H = -\alpha \dot{\Phi}, \qquad \xi \; m(\Phi) \; = \; T \, .$$

## The $\Phi$-equation

$$\ddot{\Phi} + 3H\dot{\Phi} + \frac{\partial}{\partial \Phi}\left(V - P - \frac{1}{2}\, e^{2\alpha\Phi}\dot{\Phi}_s^2\right) = 0\,,$$

## on the critical trajectory becomes

$$\dot{H} + 3H^2 = \alpha^2\left((4C_4 + Q_4)m^4 + (2C_2 + Q_2)m^2 + Q_0\right)$$
$$+\alpha^2\left((r_4 - 3p_4)\xi^4 m^4 - 2C_s\gamma^6 m^4\right).$$

$$\frac{\partial V_n}{\partial \Phi} = \alpha m^n(nC_n + Q_n),$$

$$P_4 = p_4 T^4, \qquad \rho_4 = r_4 T^4 \qquad K_s = C_s\,\frac{\gamma^2}{a^4}$$

**The gravity equation**

$$\dot{H} + 3H^2 = -\frac{2k}{a^2} + \frac{1}{2}(\rho - P) + V + \frac{1}{2}\, a\frac{\partial V}{\partial a},$$

**on the critical trajectory takes the form**

$$\dot{H} + 3H^2 = -2k\gamma^2 m^2 + \frac{1}{2}(r_4 - p_4)\xi^4 m^4$$

$$+(C_4 m^4 + C_2 m^2 + C_0) + \frac{1}{2}(Q_4 m^4 + Q_2 m^2 + Q_0)\,.$$

**The compatibility of the $\Phi$-equation and the gravity equation along the critical trajectory implies an identification of the coefficients of the monomials in $m$.**

**i) The constant terms**

$$C_0 = \frac{2\alpha^2 - 1}{2}\, Q_0\,,$$

$\rightarrow$ **determination of $\gamma$**

**ii) The $m^2$ terms, $\rightarrow$ determination of $k$:**

$$k = -\frac{2\alpha^2 - 1}{4\gamma^2}(2C_2 + Q_2)\,.$$

**iii) The $m^4$ terms relate $\xi$ to the constant $C_s$ appearing in $K_s$**

$$C_s = \frac{1}{\gamma^6}\left(\frac{4\alpha^2 - 1}{2\alpha^2}\; C_4 + \frac{2\alpha^2 - 1}{4\alpha^2}\;(Q_4 + r_4\xi^4)\right)$$
$$-\frac{1}{\gamma^6}\left(\frac{6\alpha^2 - 1}{4\alpha^2}\; p_4\xi^4\right)\,.$$

**The Hubble equation,**

$$3H^2 = -\frac{3k}{a^2} + \rho + \frac{1}{2}\dot{\Phi}^2 + \frac{1}{2}\; e^{2\alpha\Phi}\dot{\Phi}_s^2 + V\,.$$

**in the background of the critical solution :**

$$\left(\frac{6\alpha^2-1}{6\alpha^2}\right) 3H^2 = \rho + V + \frac{1}{2}\, e^{2\alpha\Phi}\dot{\Phi}_s^2 - \frac{3k}{a^2}$$

**The dilatation factor in frond of $3H^2$, can be absorbed by a redefinition of :**
$C_R$, $\lambda$ **and** $\hat{k}$ $\longrightarrow$

$$3H^2 = 3\lambda - \frac{3\hat{k}}{a^2} + \frac{C_R}{a^4}\,,$$

$$3\lambda = \frac{2\alpha^2-1}{6\alpha^2-1}\, 3\alpha^2 Q_0\,,$$

$$\hat{k} = \frac{\alpha^2}{\gamma^2}\left(\frac{2}{6\alpha^2-1}\,\xi^2 M^2 - C_2 - \frac{3}{2}\,\frac{2\alpha^2-1}{6\alpha^2-1}\,Q_2\right),$$

$$C_R = \frac{3}{2\gamma^4}\left((r_4 - p_4)\,\xi^4 \;+\; 2C_4 \;+\; \frac{2\alpha^2-1}{6\alpha^2-1}\,Q_4\right).$$

**The lesson of this exercise is that :**

- **the cosmological constant scale, $\lambda$**

- **the curvature scale, $\hat{k}$**

**are both generated by "the scaling violating terms" of the thermal effective potential.**

- **In the absence of the scaling violating terms (or when these terms are negligible), the "no-scale modulus $\Phi$ couples to the total trace of the energy momentum tensor.**

- **This special case was studied in 1986 by I. Antoniadis and C. Kounnas. They found that the critical trajectory is the only stable solution under any field fluctuation.**

**In that case, $\lambda = \hat{k} = 0$, the critical trajectory is an attractor at late times giving rise to a radiation evolving universe with :**

$$a^2 \sim t, \quad T^2 \sim m_\Phi^2 \sim 1/t, \quad V \sim 1/t^2.$$

**In the general case $\lambda \neq 0, \hat{k} \neq 0$, the time evolution of $a$, $T$ and $\Phi$ is similar to**

**the radiation-deformed de Sitter Solutions!**

**H.Firouzjahi, S.Sarangi, S.H.H.Tye, 04 ;**
**S.Sarangi, S.H.H.Tye, 05;**
**R. Brustein, S.P. de Alvis, 06;**
**C. Kounnas, H. Partouche, 07; . . .**

$$a_+^2 = \frac{1}{\lambda}\left(ch^2\left(\sqrt{\lambda}\ t\right) + \epsilon_\rho^2\right)$$

$$a_-^2 = \frac{1}{\lambda}\left(-sh^2\left(\sqrt{\lambda}\ t\right) + \epsilon_\rho^2\right)$$

**The cosmological solutions $a_-$ and $a_+$ are connected by a $\Phi$-Gravitational Instanton**

$$a_E^2 = \frac{1}{\lambda}\left(cos^2\left(\sqrt{\lambda}\ \tau\right) + \epsilon_\rho^2\right)$$

**with a transition probability ( $a_- \ \rightarrow \ a_+$ )**

$$< \Psi_- || \Psi_+ >= \ P \ \sim e^{\left(\frac{2}{3\lambda} \ - \ \frac{\chi_\rho}{\lambda^2}\right)}$$

**• $\chi_\rho$ is proportional to the number of the effective marginal and/or thermal degrees of freedom at the temperature scale $T_0$, defined at the transition point.**

**C. Kounnas, H. Partouche, 07**

- $\Psi_{\pm}$ **is the wave-function of the universe.**

**J.B. Hartle, S.W. Hawking, 83;**
**A. Vilenkin, 82, 83;**
**A.D. Linde, 84;**
**H.Firouzjahi, S.Sarangi, S.H.H.Tye, 04;**
**S.Sarangi, S.H.H.Tye, 05;**
**R. Brustein, S.P. de Alvis, 06;**
**C. Kounnas, H. Partouche, 07; . . . . . . ;**

## 5. String Perspectives and Conclusion

**At classical string level it seems difficult to construct exact cosmological string solutions and is even more difficult to obtain de Sitter like inflationary solutions even in lower than four dimensions.**

**• Consider for instance the euclidian version of $S^3$ which is an exact conformal field theory base on $SU(2)_k$ WZW model.**

**However, the $SU(2)_k$ WZW model does not admit any real-time analytic continuation due to the existence of a non-trivial torsion $H_{ijk}$ which becomes imaginary!!**

**I.Antoniadis, C.Bachas, A.Sagnotti, 90;**
**P.K Townsend 01;**
**J. Sonner, P.K Townsend 06;**
**C.Bachas, C.Kounnas,**
**D.Orlando, M.Petropoulos 07;**

. . .

**• The only known cosmological solution based on an exact conformal field theory is that of $SL(2,R)/U(1)_{-|k|} \times K$.**

**Its euclidian version is also well defined by the parafermionic T-fold.**

**C.Kounnas, D.Luest 92;**
**L.Coralba, M.S.Costa, C.Kounnas 02;**
**C.Kounnas, N.Toumbas, J.Troost O7;**

**. . .**

- **In all String cosmological models with a well define euclidian version,**
**(like for instance the $SL(2,R)/U(1)_{-|k|} \times K$),**
**the super-string analog of:**
**"the Stringy wave function of the universe"**
**can be unambiguously defined.**

**Furthermore the transition probabilities can be evaluated at the string level.**

**C.Kounnas, N.Toumbas, J.Troost O7.**

## *Concluding Remark*

- **Our proposal however goes even beyond the scope of the above statement; namely *towards to :***

***The plausible existence of cosmological super-string solutions (Inflationary or not)***

***which are generated dynamically***

**at the quantum sting level**

***from a flat classical space-time and***

**spontaneously broken supersymmetry**

***(no-scale radiative-induced cosmology).***