# INFLATION VIA HIGGS-DILATON POTENTIAL IN TWO TIME PHYSICS

Vo Quoc Phong, Le Minh Ngoc

Department of Theoretical Physics
Ho Chi Minh City University of Science

Based on Itzhak Bars, arXiv:1004.0688v2

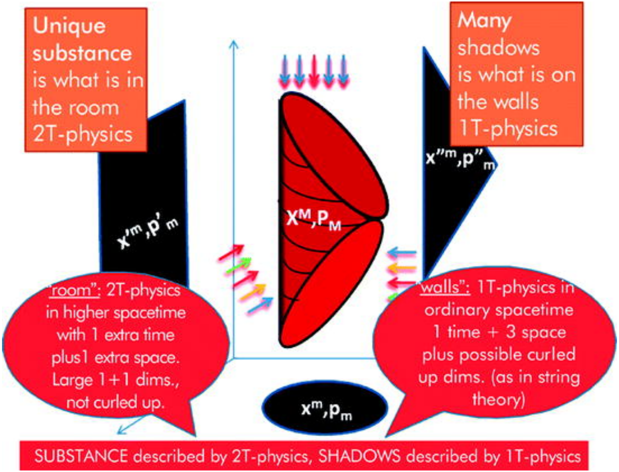
ICISE QUY NHON VIETNAM

15th Rencontres du Vietnam: Cosmology, 2019

## Overview

1. Two-Time physics (2T)
2. Inflation
3. Inflation via Higgs-Dilaton potential in 2T

# What is Two-Time Physics (2T)?


Unique substance is what is in the room 2T-physics
Many shadows is what is on the walls 1T-physics
x'm,p'm
X^M,P_M
x''m,p''m
"room": 2T-physics in higher spacetime with 1 extra time plus1 extra space. Large 1+1 dims., not curled up.
"walls": 1T-physics in ordinary spacetime 1 time + 3 space plus possible curled up dims. (as in string theory)
x^m,p_m
SUBSTANCE described by 2T-physics, SHADOWS described by 1T-physics

# I. TWO-TIME PHYSICS

## a. Tensor metric in 2T

2T model is based on symplectic group $\mathrm{Sp}(2,\mathbf{R})$ which relates to the symmetry between position and momentum.

Position-momentum doublet $X_i^M = (X_1^M, X_2^M)$

$$\begin{cases} X_1^M = X^M & \text{is the space-time in 2T,} \\ X_2^M = P^M & \text{is the energy-momentum in 2T.} \end{cases} \tag{1}$$

**1T**

$(d-1)$ spacelike dimensions and $1$ timelike dimension.

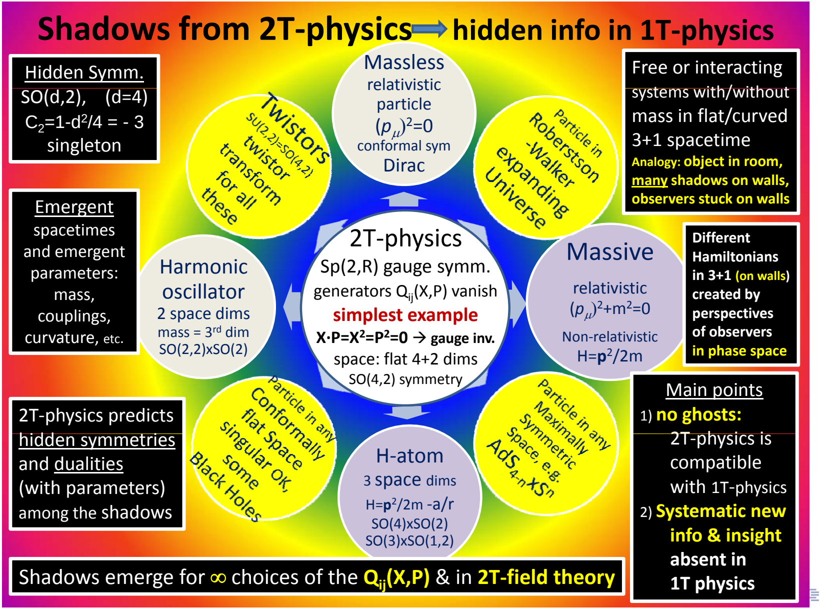
$$g_{\mu\nu} = \text{diag}(-1,1,1,1), \quad \mu,\nu = 0,1,2,3.$$

**2T**

$d$ spacelike dimensions and $2$ timelike dimensions.

$$\eta_{MN} = \text{diag}(\mathbf{-1},\mathbf{1},-1,1,1,1), \quad M,N = \mathbf{0}',\mathbf{1}',0,1,2,3.$$

# Why do we need 2T?


Shadows from 2T-physics ⟹ hidden info in 1T-physics
Hidden Symm.
SO(d,2), (d=4)
$C_2=1-d^2/4 = -3$
singleton
Emergent spacetimes and emergent parameters: mass, couplings, curvature, etc.
2T-physics predicts hidden symmetries and dualities (with parameters) among the shadows
Massless relativistic particle
$(p_\mu)^2=0$
conformal sym
Dirac
Twistors
SU(2,2)=SO(4,2)
twistor transform for all these
Particle in Robertson-Walker expanding Universe
Free or interacting systems with/without mass in flat/curved 3+1 spacetime
Analogy: object in room, many shadows on walls, observers stuck on walls
Harmonic oscillator
2 space dims
mass = 3rd dim
SO(2,2)xSO(2)
2T-physics
Sp(2,R) gauge symm.
generators $Q_{ij}(X,P)$ vanish
simplest example
$X\cdot P=X^2=P^2=0$ → gauge inv.
space: flat 4+2 dims
SO(4,2) symmetry
Massive
relativistic
$(p_\mu)^2+m^2=0$
Non-relativistic
$H=\mathbf{p}^2/2m$
Different Hamiltonians in 3+1 (on walls) created by perspectives of observers in phase space
Particle in any Conformally flat Space singular OK, some Black Holes
H-atom
3 space dims
$H=\mathbf{p}^2/2m - a/r$
SO(4)xSO(2)
SO(3)xSO(1,2)
Particle in any Maximally Symmetric Space, e.g. $AdS_{4-n}xS_n$
Main points
1) no ghosts:
2T-physics is compatible with 1T-physics
2) Systematic new info & insight absent in 1T physics
Shadows emerge for ∞ choices of the $Q_{ij}(X,P)$ & in 2T-field theory

## b. Lagrangian of Standard Model in 2T

$$\begin{pmatrix} u^L \\ d^L \end{pmatrix}_{\frac{1}{3}}, \left(u^R\right)_{\frac{4}{3}}, \left(d^R\right)_{-\frac{2}{3}}, \begin{pmatrix} \nu_e^L \\ e^L \end{pmatrix}_{-1}, \left(\nu_e^R\right)_0, \left(e^R\right)_{-2}$$ the first generation.

$$\begin{pmatrix} c^L \\ s^L \end{pmatrix}_{\frac{1}{3}}, \left(c^R\right)_{\frac{4}{3}}, \left(s^R\right)_{-\frac{2}{3}}, \begin{pmatrix} \nu_\mu^L \\ \mu^L \end{pmatrix}_{-1}, \left(\nu_\mu^R\right)_0, \left(\mu^R\right)_{-2}$$ the second generation.

$$\begin{pmatrix} t^L \\ b^L \end{pmatrix}_{\frac{1}{3}}, \left(t^R\right)_{\frac{4}{3}}, \left(b^R\right)_{-\frac{2}{3}}, \begin{pmatrix} \nu_\tau^L \\ \tau^L \end{pmatrix}_{-1}, \left(\nu_\tau^R\right)_0, \left(\tau^R\right)_{-2}$$ the third generation.

### The Lagrangian of Standard Model in 4+2 dimensions

$$L(A, \Psi^{L,R}, H, \Phi) = L(A) + L(A, \Psi^{L,R}) + L(\Psi^{L,R}, H) + L(A, H, \Phi). \tag{2}$$

where $A$ are gauge bosons, $\Psi^{L,R}$ are fermions, $H$ is Higgs and $\Phi$ is Dilaton.

- Resolution of the strong CP violation problem of QCD.
- Dilaton driven electroweak spontaneous breakdown.

## c. Higgs-Dilaton potential from 2T to 1T

$$L(A,H,\Phi) = \frac{1}{2}\Phi\partial^2\Phi + \frac{1}{2}\left[H^\dagger D^2 H + (D^2H)^\dagger H\right] - \lambda(H^\dagger H - \alpha^2\Phi^2)^2 - V(\Phi), \quad (3)$$

The Higgs-Dilaton potential

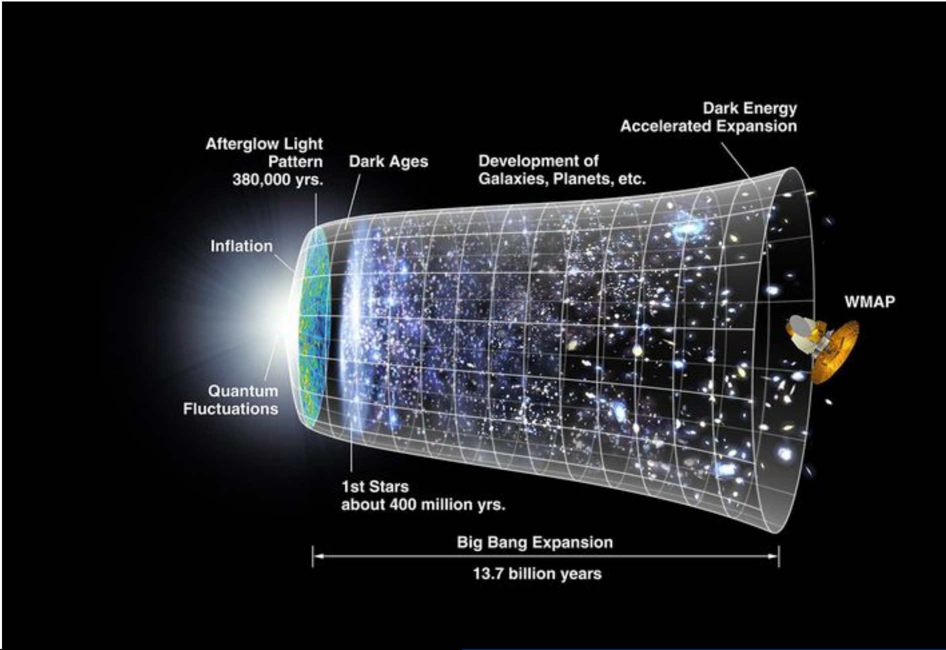
$$V(H,\Phi) = \lambda(H^\dagger H - \alpha^2\Phi^2)^2 + V(\Phi). \quad (4)$$

The reduced formulations, using gauge fixing technology

$$\begin{cases} \Phi(X) & \longrightarrow \frac{1}{\kappa}\phi(x), \\ H(X) & \longrightarrow \frac{1}{\kappa}h(x). \end{cases} \quad (5)$$

The reduced Higgs-Dilaton potential from 2T to 1T

$$V(H,\Phi) \longrightarrow \frac{\lambda}{\kappa^4}(h^2 - \alpha^2\phi^2)^2 + V(\phi). \quad (6)$$


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
380,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

## II. INFLATION

Two Slow-roll conditions: $\dot{\varphi}^2 \ll V(\varphi)$ and $\ddot{\varphi} \ll 3H\dot{\varphi}$.
Two slow-roll parameters $\varepsilon, \eta \ll 1$.

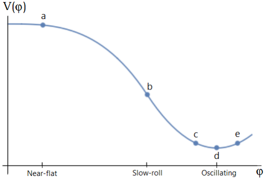



Figure: Slow-roll (New) inflation $V(\varphi) = -\frac{\lambda}{4}\varphi^4 + \frac{m^2}{2}\varphi^2 + V(0)$.

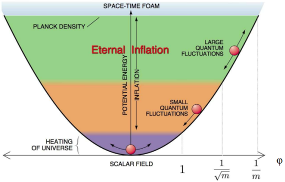



Figure: Chaotic inflation $V(\varphi) = \frac{1}{2}m^2\varphi^2$.

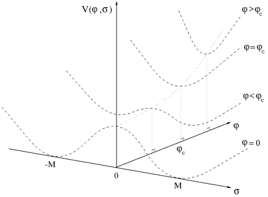
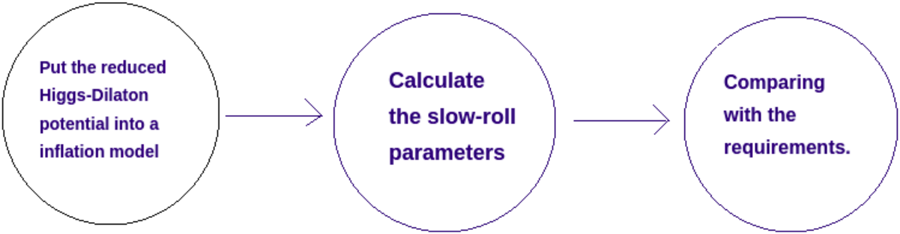



Figure: Hybrid inflation $V(\varphi, \sigma) = \frac{1}{4\lambda}M^4 + \frac{1}{4}\lambda\sigma^4 + \frac{1}{2}(-M^2 + g^2\varphi^2)\sigma^2 + \frac{1}{2}m^2\varphi^2$.

# How about Inflation in 2T?

## III. Inflation via Higgs-Dilaton potential in 2T



## i. Higgs-Dilaton potential in New Inflation

Dilaton field $\phi$ plays the role of inflaton in New inflation.

$$V(\phi) = \frac{\lambda}{4}(\phi^2 - \phi_0^2)^2. \tag{7}$$

The two potential slow-roll parameters

$$\begin{cases} \varepsilon_V = 8M_P^2 \frac{\phi^2}{(\phi^2-\phi_0^2)^2}, \\ \eta_V = 4M_P^2 \left[\frac{2\phi^2}{(\phi^2-\phi_0^2)^2} + \frac{1}{\phi^2-\phi_0^2}\right]. \end{cases} \tag{8}$$

Satisfy!!!

## ii. Higgs-Dilaton potential in Chaotic Inflation

Dilaton also plays the role of inflaton in Chaotic inflation.

$$V(\phi) = \lambda\phi^4. \tag{9}$$

The initial values of two slow-roll parameters

$$\begin{cases} \varepsilon_i = \frac{1}{1-N}, \\ \eta_i = \frac{3}{2(1-N)}. \end{cases} \tag{10}$$

Satisfy!!!

## iii. Higgs-Dilaton potential in Hybrid Inflation

Higgs plays the non-inflation role and Dilaton plays the inflation role.
Unitary gauge for Higgs-Dilaton potential in Eq.(4) with electroweak scale $v$

$$\begin{cases} H^0(x) = \frac{1}{\kappa}\left[v + h(x)\right], \\ \Phi(x) = \frac{1}{\alpha\kappa}\left[v + \alpha\phi(x)\right]. \end{cases} \tag{11}$$

The 1T Higgs-Dilaton potential

$$\begin{aligned} V(h,\phi) = {} & \frac{\lambda}{4}h^4 + \lambda v h^3 + \frac{\lambda}{2}(-\alpha^2\phi^2 - 2v\alpha\phi + 2v^2)h^2 - \lambda(v\alpha^2\phi^2 + 2v^2\alpha\phi)h \\ & + \frac{\lambda}{4}\alpha^4\phi^4 + \lambda v\alpha^3\phi^3 + \lambda v^2\alpha^2\phi^2. \end{aligned} \tag{12}$$

Unsatisfied :(

## Summary

- Two-Time physics is hopefully an answer for the problems with One-Time.
- Two-Time physics can be a good candidate for studying extra-dimension in the early stage of our Universe.

## Outlook

For further discuss

- Testing the reduced Higgs-Dilaton potential with other recent inflation models.
- Using the other higher-dimensional models.


THANKS
FOR
LISTENING