Walking-Dilaton Hybrid Inflation with gauged B-L in a Model with Dynamical Scalegenesis

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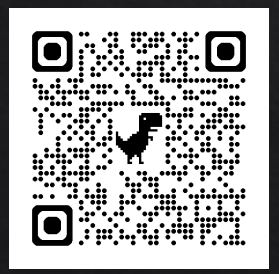

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Introduction

Unsatisfactory points of electroweak symmetry breaking

$$V(H) = m_H^2 |H|^2 + \lambda_H |H|^4 \qquad (m_H^2 < 0)$$

assuming negativeness for unique dimensionful term

Simplest solution : scale invariance

$$V(H) = \cancel{m_H^2 |H|^2} + \lambda_H |H|^4$$

How to generate scale becomes problem

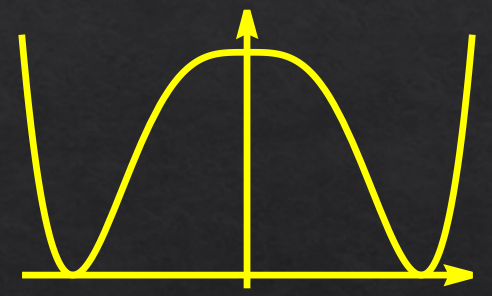
Introduction

Coleman-Weinberg mechanism

[Coleman, Weinberg(1973)]
[Barenboim, Chun, Lee (2013)]

Generates scale by quantum effects
even starting from scale symmetric Lagrangian

$$V_{\rm CW}(H) = \lambda_H |H|^4 (\log H/v + A)$$



Another unsatisfactory point : cannot apply to EWSB

However, CW potential is naturally flat near the origin

➡ suitable for realizing inflation

Introduction

Small field inflation by CW potential [Barenboim, Chun, Lee (2013)]

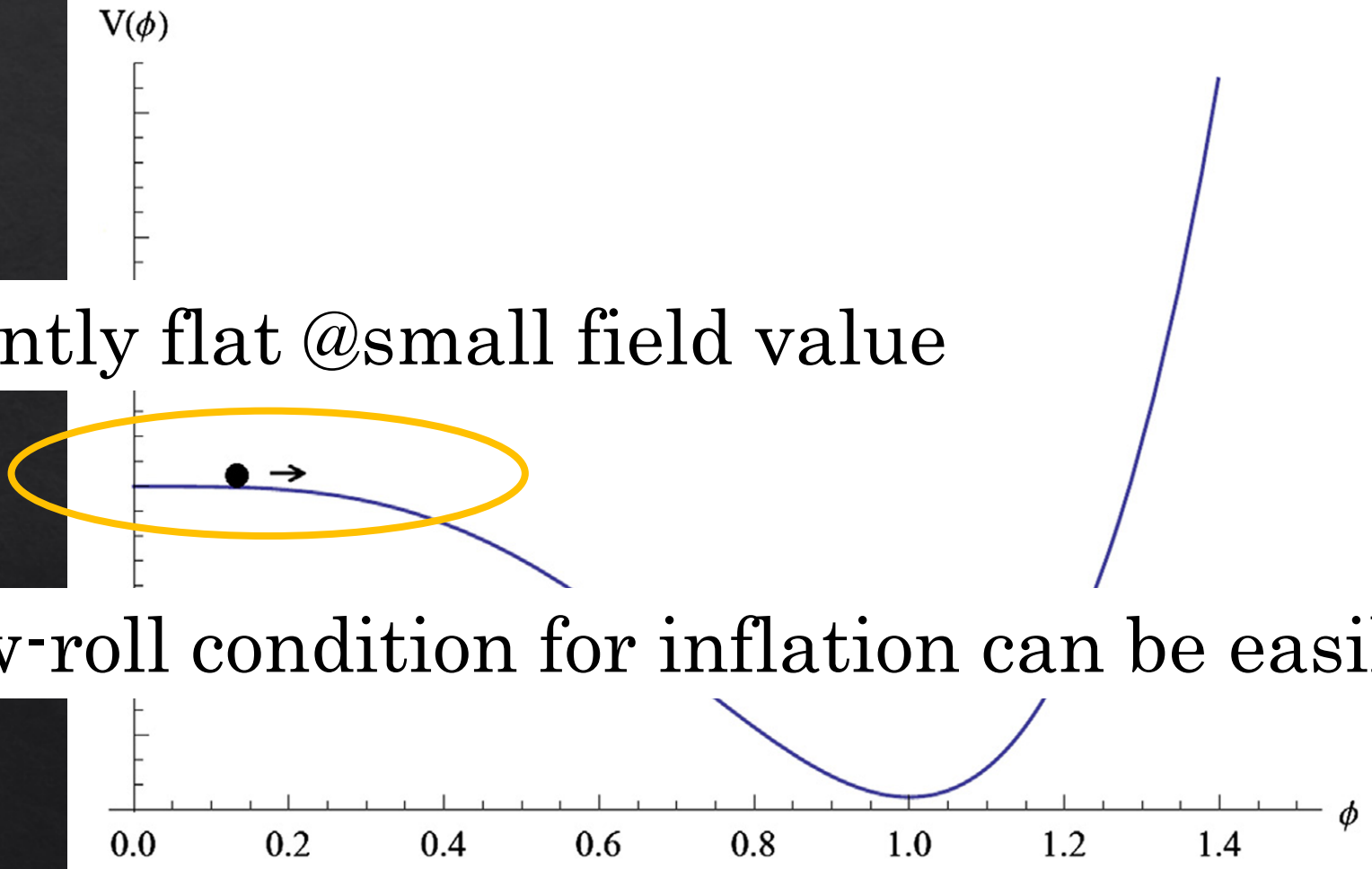


Fig. 1. The CW potential realizing a small field inflation.

Sufficiently flat @small field value

Slow-roll condition for inflation can be easily realized

Introduction

Small field inflation by CW potential [Barenboim, Chun, Lee (2013)]

Sufficiently flat @small field value

However, initial point is ambiguous

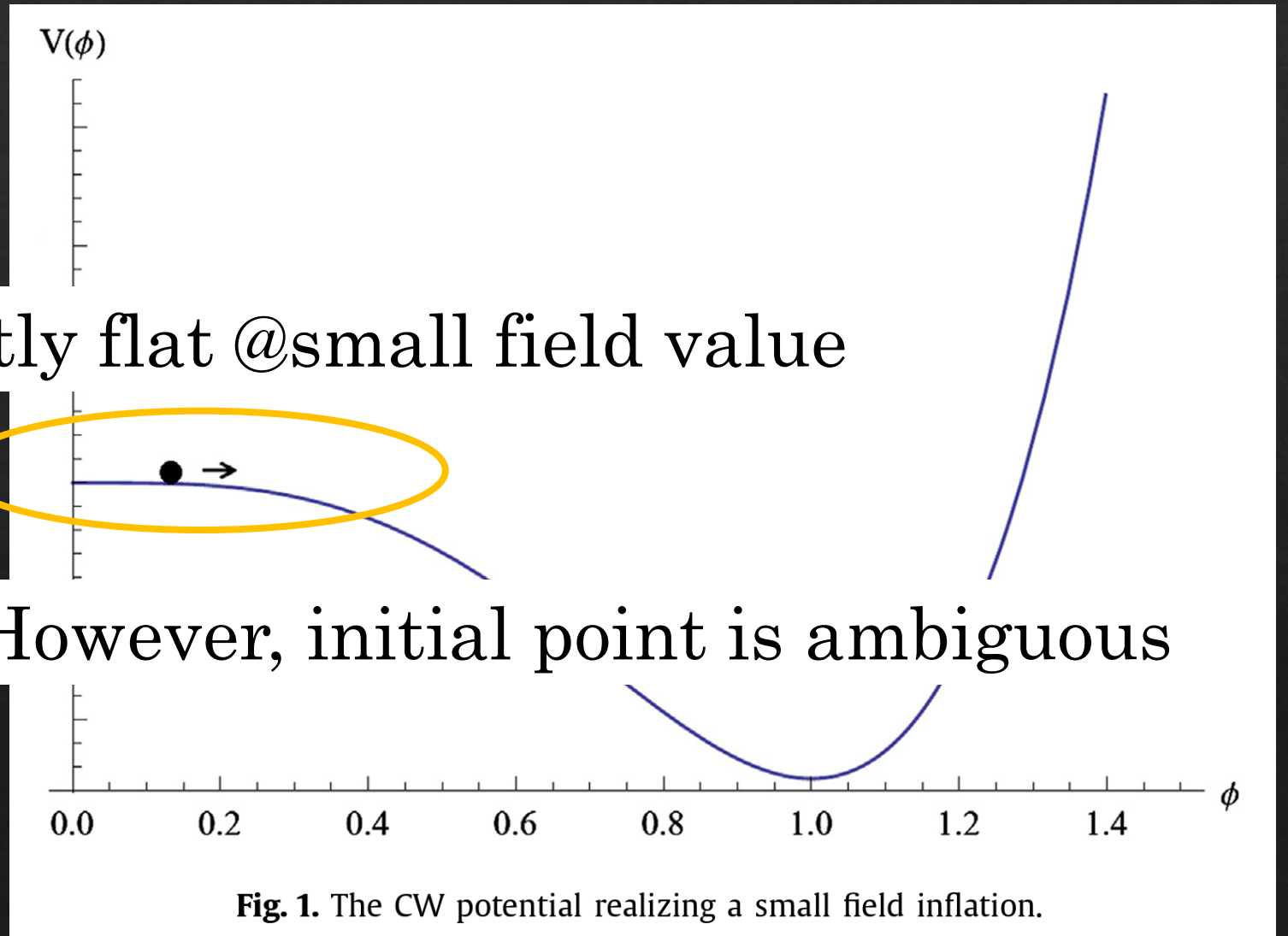


Fig. 1. The CW potential realizing a small field inflation.

Introduction

Walking dilaton inflation [H.I., Matsuzaki (2020)]

Model setup:
SM w/ classical scale invariance
+ many flavor hidden strong dynamics

walking dynamics is realized

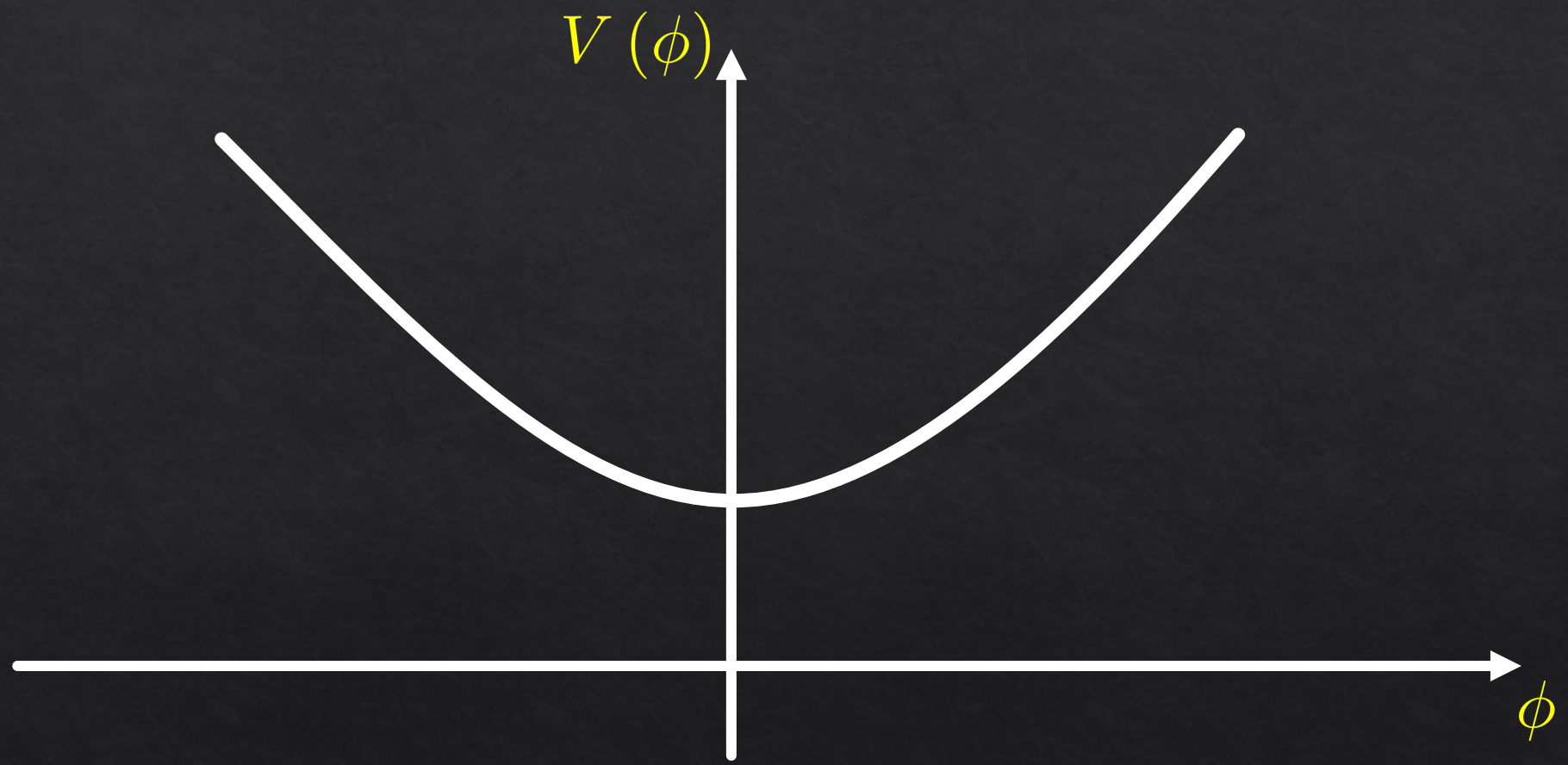
dilaton=inflaton

Further benefits (skip all the detail) :
scale can be generated via bosonic seesaw mechanism

[Calmet (2003); Kim (2005); Haba, Kitazawa, Okada (2009); Antipin, Redi, Strumia (2015); Haba, H. I., Okada, Yamaguchi (2016); Haba, H. I., Kitazawa, Yamaguchi (2016); H. I., Matsuzaki, Yamaguchi (2016); H. I., Matsuzaki, Yamaguchi (2017); Haba, Yamada (2017); Haba, Yamada (2017); H. I., Matsuzaki, Okawa, Omura (2017)]

Walking dilaton inflation [H.I., Matsuzaki (2020)]

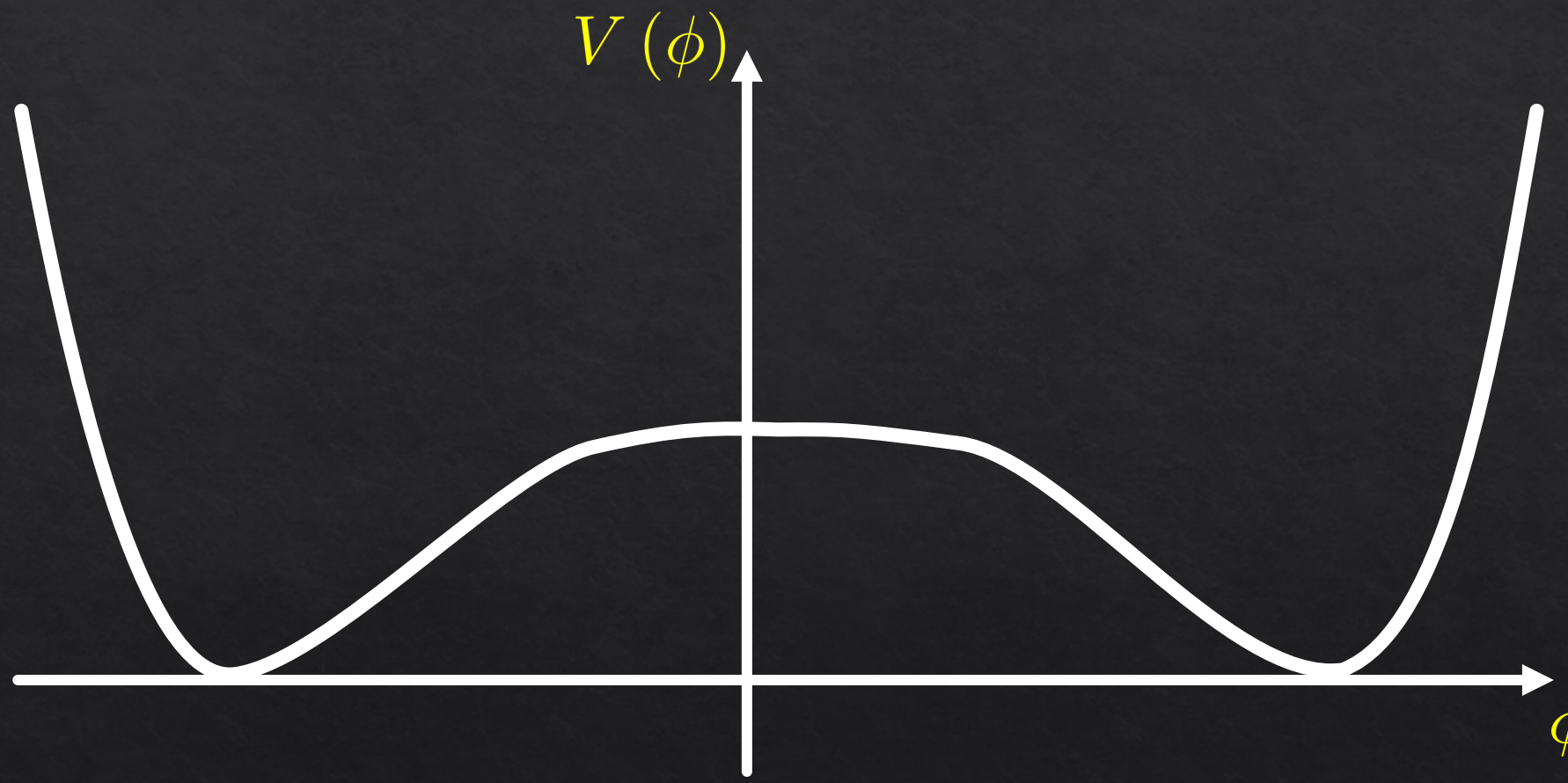
Dilaton potential: CW-type + thermal corrections



Thermal potential traps dilaton at origin

Walking dilaton inflation [H.I., Matsuzaki (2020)]

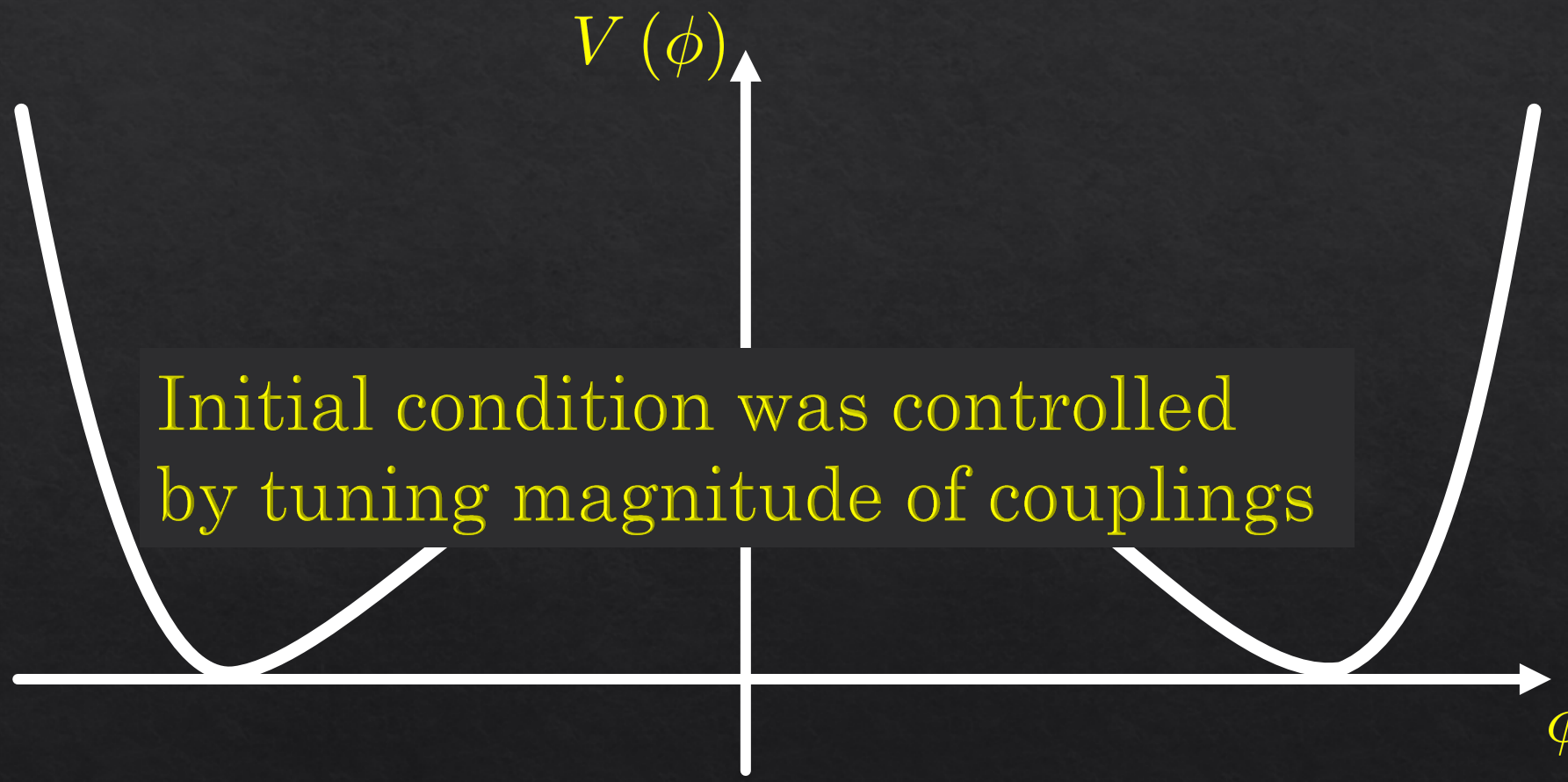
Dilaton potential: CW-type



CW potential becomes dominant but still not to roll down

Walking dilaton inflation [H.I., Matsuzaki (2020)]

Dilaton potential: CW-type



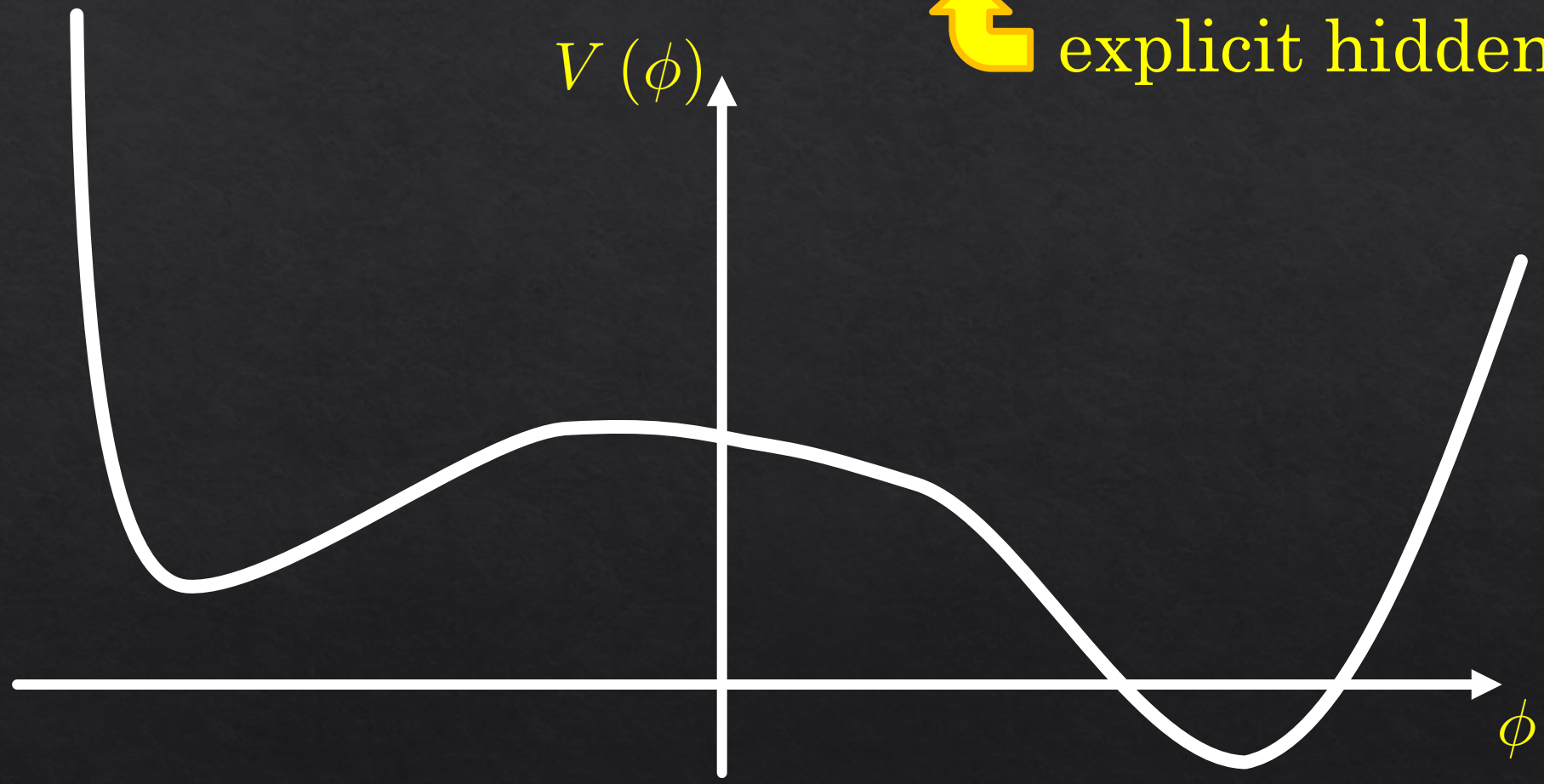
Initial condition was controlled
by tuning magnitude of couplings

CW potential becomes dominant but still not to roll down

Walking dilaton inflation [H.I., Matsuzaki (2020)]

Dilaton potential: CW-type + linear term [H.I., Matsuzaki, Zhang (2023)]

explicit hidden **c**SB



Linear term determines where to start rolling

Walking dilaton inflation [H.I., Matsuzaki (2020)]

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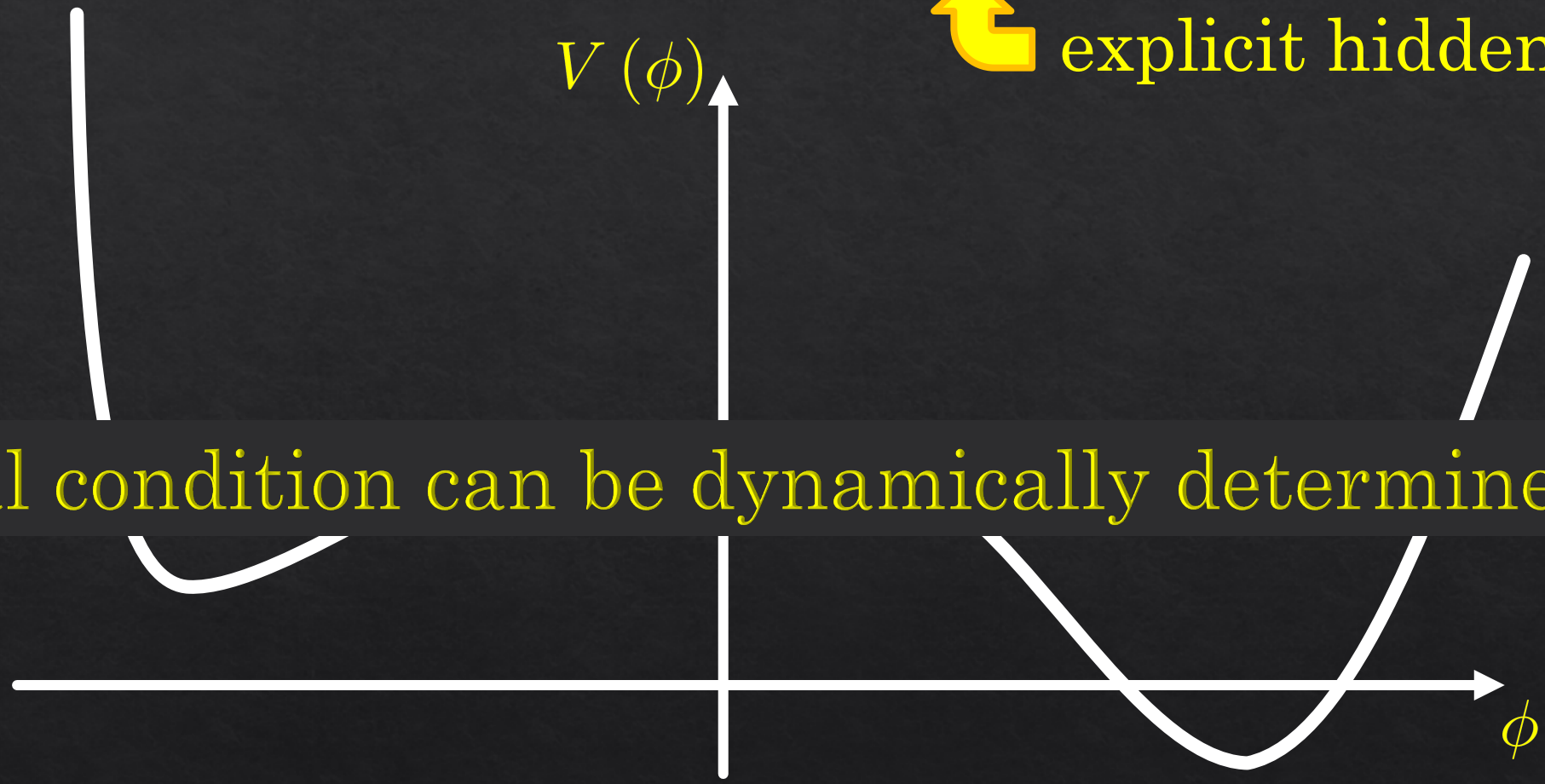


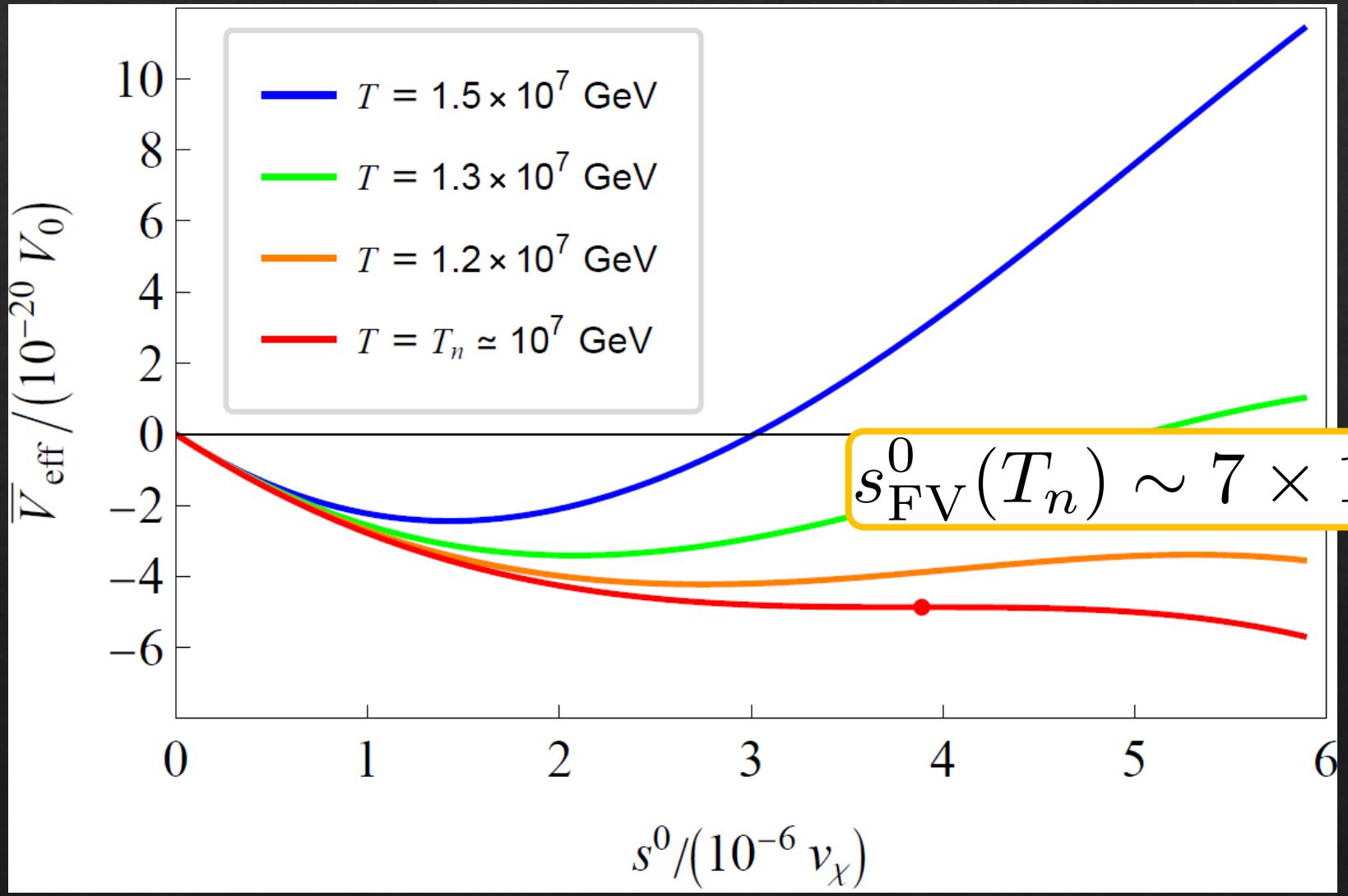
Initial condition can be dynamically determined!!

Linear term determines where to start rolling

Walking dilaton inflation w/ linear term

[H.I., Matsuzaki, Zhang (2023)]

Temperature evolution of dilaton potential



$$s^0_{\rm FV}(T_n) \sim 7 \times 10^9\,{\rm GeV}$$

Walking dilaton inflation w/ linear term [H.I., Matsuzaki, Zhang (2023)]

Short summary

- Classical scale invariance + hidden strong dynamics

  Walking dynamics gives a scalar, dilaton,
  which can be an inflaton

- CW-type potential of dilaton with linear term

  Flatten potential at around the origin
  and initial condition for inflation are naturally realized

Inflation itself can be explained by the current setup

Is there any possible phenomenological extension?

Model [H.I., Matsuzaki, Zhang (2023)]

Particle contents:

walking

	$\mathrm{SU}(3)_{\mathrm{HC}}$	$\mathrm{U}(1)_{B-L}$	$\mathrm{SU}(3)_c$	$\mathrm{SU}(2)_W$	$\mathrm{U}(1)_Y$
$\psi^1_{L/R}$	3	$+1$	1	1	0
$\psi^2_{L/R}$	3	-1	1	1	0
$\psi^3_{L/R}$	3	0	1	1	0
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
$\psi^8_{L/R}$	3	0	1	1	0
ϕ	1	$+2$	1	1	0
N_R	1	-1	1	1	0
q_L	1	$1/3$	3	2	$1/6$
l_L	1	-1	1	2	$-1/2$
u_R	1	$1/3$	3	1	$2/3$
d_R	1	$1/3$	3	1	$-1/3$
e_R	1	-1	1	1	-1
H	1	0	1	2	$1/2$

Model [H.I., Matsuzaki, Zhang (2023)]

Particle contents:

B-L braking

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H	1	0	1	2	$1/2$

can be extended to EWSB

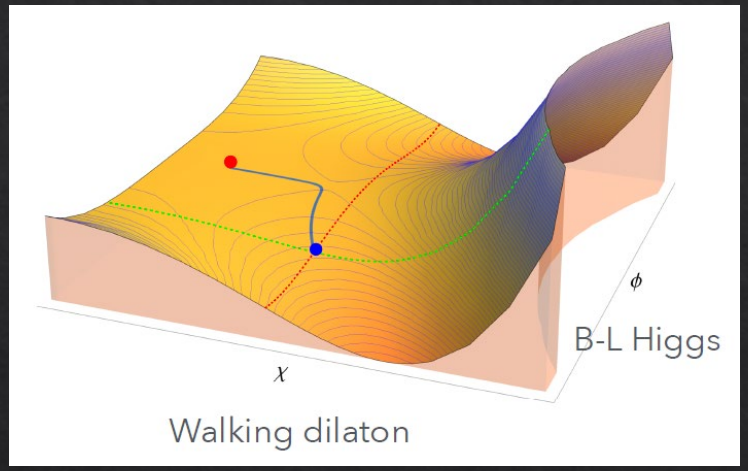
Walking-dilaton hybrid inflation [Liu, H.I., Matsuzaki, Zhang (2024)]

B-L gauge symmetry is introduced

Two directions:

walking dilaton

B-L Higgs



Rough sketch of inflation dynamics;

walking dilaton dynamics determines initial condition

B-L Higgs determines end point of the inflation

Walking-dilaton hybrid inflation [Liu, H.I., Matsuzaki, Zhang (2024)]

Predictions (all the details are skipped)

$r \lesssim 10^{-25}$

Requirements: $N|_{\rm obs} \simeq 40\text{–}60, \quad \Delta^2_{\rm R}|_{\rm obs} \simeq 2.137 \times 10^{-9}, \quad n_s|_{\rm obs} \simeq 0.968\,.$

B-L breaking scale

$v_{\text{B-L}} \sim 10^9$ GeV

Lightest hidden pion mass

$m_\pi \sim 500$ GeV

Too small x-sec to find

Walking-dilaton hybrid inflation [Liu, H.I., Matsuzaki, Zhang (2024)]

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B-L breaking scale

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Majorana mass scale

Type-I seesaw

Thermal leptogenesis $\Leftrightarrow$ $T_R \lesssim 10^5$ GeV

(c.f. [Enomoto, H.I., Matsuzaki, and Wang (2022), Matsuzaki, Wang, and Wang (2024)])

Conclusions

Origin of mass & inflation are still open questions

Walking-dilaton hybrid inflation can give solution

SM w/ classical scale invariance
+ hidden strong dynamics w/ many flavor
+ B-L gauge symmetry
+ Bosonic seesaw mechanism for symmetry breaking

B-L breaking scale is tightly constrained: $v_{\text{B-L}} \sim 10^9$ GeV

Our framework offers a unified origin
for both inflation and Dark Matter [Hashino, H.I., Matsuzaki, Zhang (2025)]

Thanks for your attentions!
謝謝您