

# Dynamical Systems and Superstring Phases in the Early Universe

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Based on arxiv: 2505.14187 [hep-ph] (*JHEP*)

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# Key ingredients

## 1. String Theory

- Extra dimensions

⇒ **Moduli fields** = scalars controlling their size and shape

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⇒ **Moduli fields** = scalars controlling their size and shape

... which set all physical scales

... and could be evolving in the early Universe

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**2. Cosmic Strings**

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**2. Cosmic Strings**

- Tension  $\mu = E/L \Rightarrow \mu = \mu(\Phi) \Rightarrow \mu(t)$

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**1. String Theory  $\Rightarrow$  Moduli  $\Phi(t)$**

**2. Cosmic Strings  $\Rightarrow \mu = \mu(\Phi) \Rightarrow \mu(t)$**

**3. Time-dependent tensions**

- Sub-horizon loops of cosmic strings grow if the tension decreases [2406.12637 [hep-ph]]

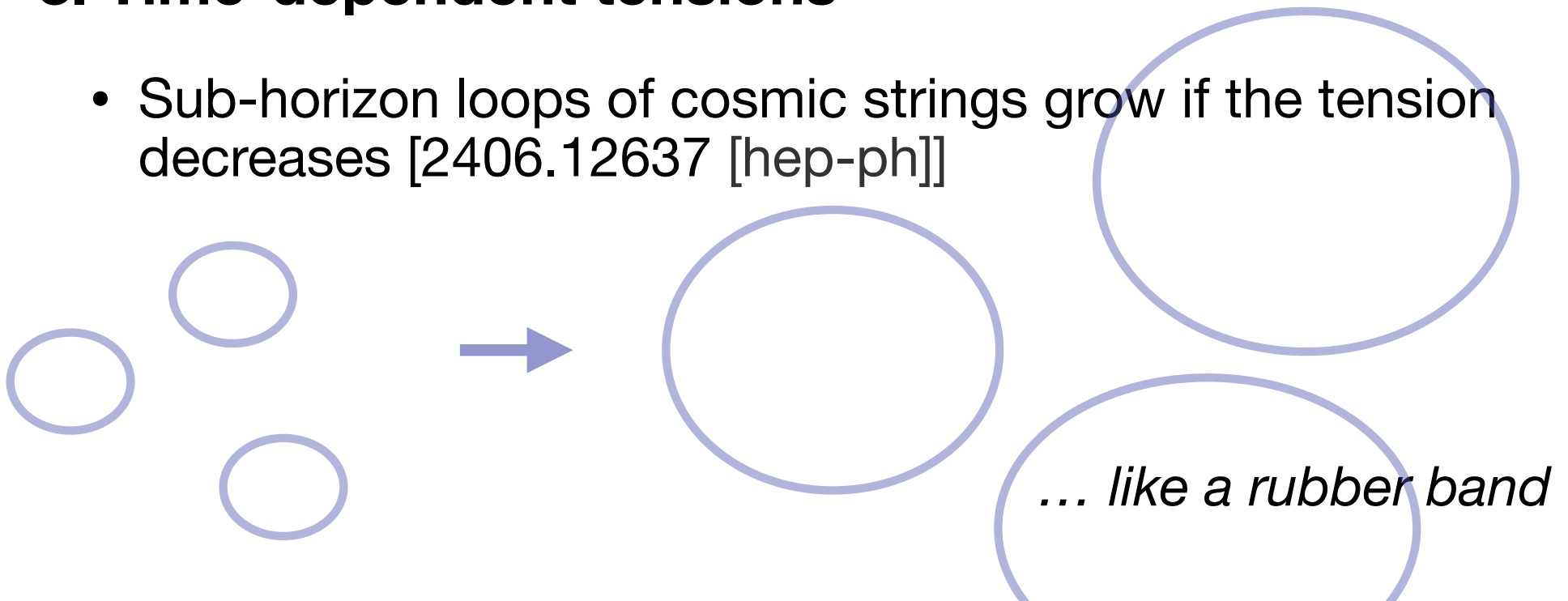
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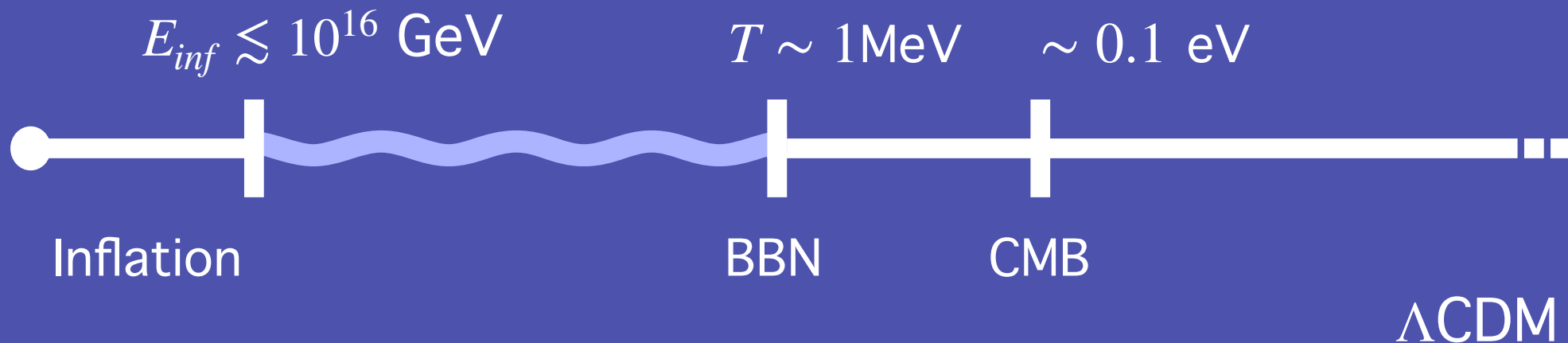
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# Motivation

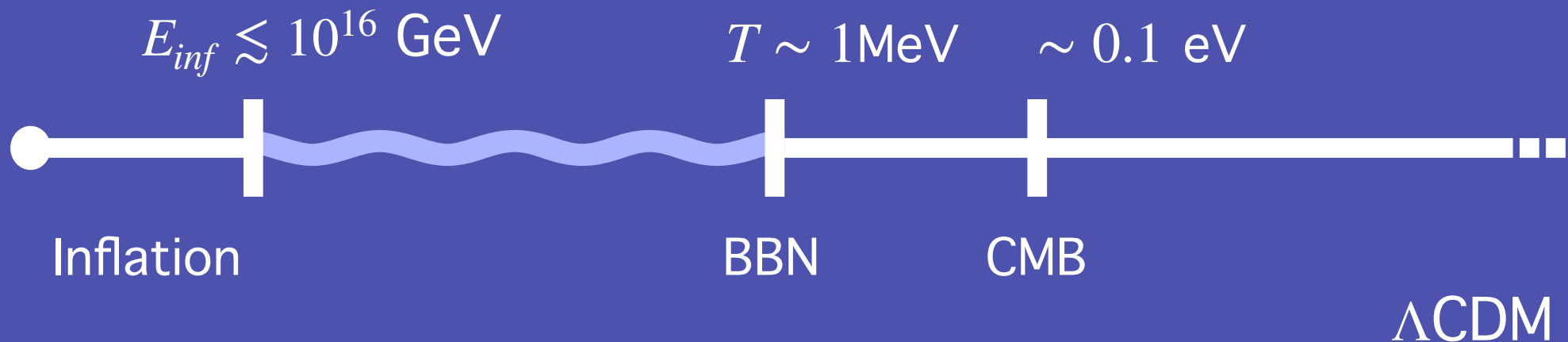
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  - Observational constraints: BBN and CMB
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- **Early Universe**
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→ **GOAL:** String Theory Pheno



# Dynamical system analysis

## System of equations

- **Ingredients**

- FLRW background,  $a(t)$
- A modulus  $\Phi(t)$  with  $V(\Phi)$
- A population of sub-horizon cosmic string loops  $\rho_{\text{loops}}(a, \Phi)$

# Dynamical system analysis

## System of equations

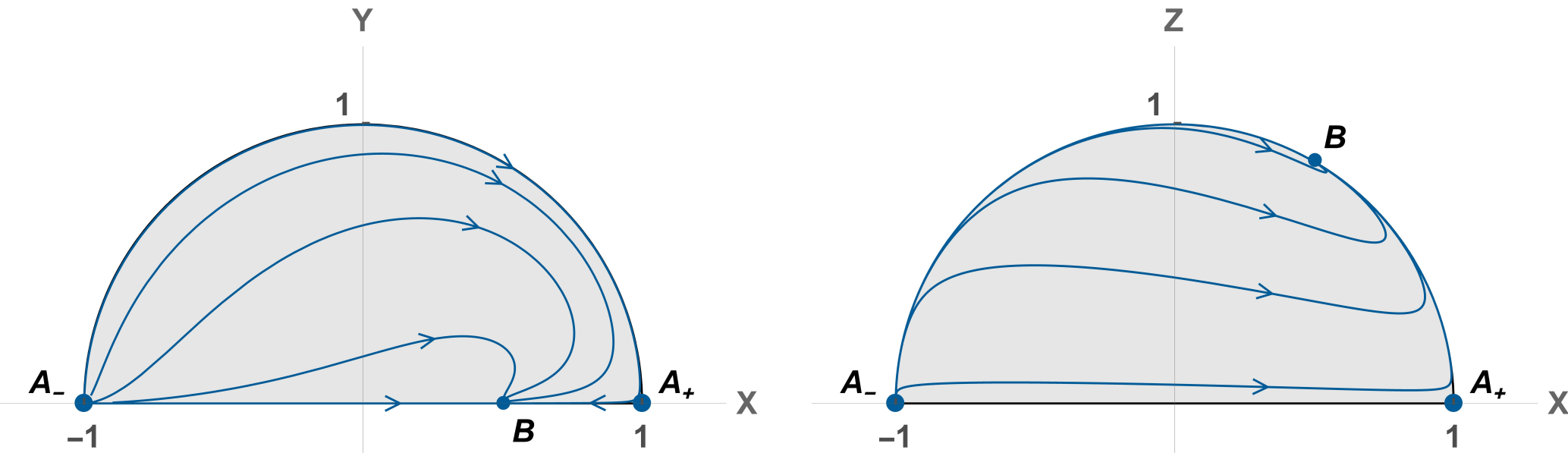
- Ingredients

$$a(t) \quad + \text{ modulus } \Phi(t) \text{ with } V(\Phi) \quad + \rho_{\text{loops}}(a, \Phi)$$

- EOM 
$$\left\{ \begin{array}{l} 3M_P^2 H^2 = \dot{\Phi}^2/2 + V(\Phi) + \rho_{\text{loops}} \\ \ddot{\Phi} + 3H\dot{\Phi} + \frac{\partial V}{\partial \Phi} + \frac{\partial \rho_{\text{loops}}}{\partial \Phi} = 0 \\ \dot{\rho}_{\text{loops}} + 3H\rho_{\text{loops}} - \frac{\partial \rho_{\text{loops}}}{\partial \Phi} \dot{\Phi} = 0 \end{array} \right.$$

# Dynamical system analysis

## Results: LVS and F-strings



**Fig. 1** Evolution of the energy fractions in phase space

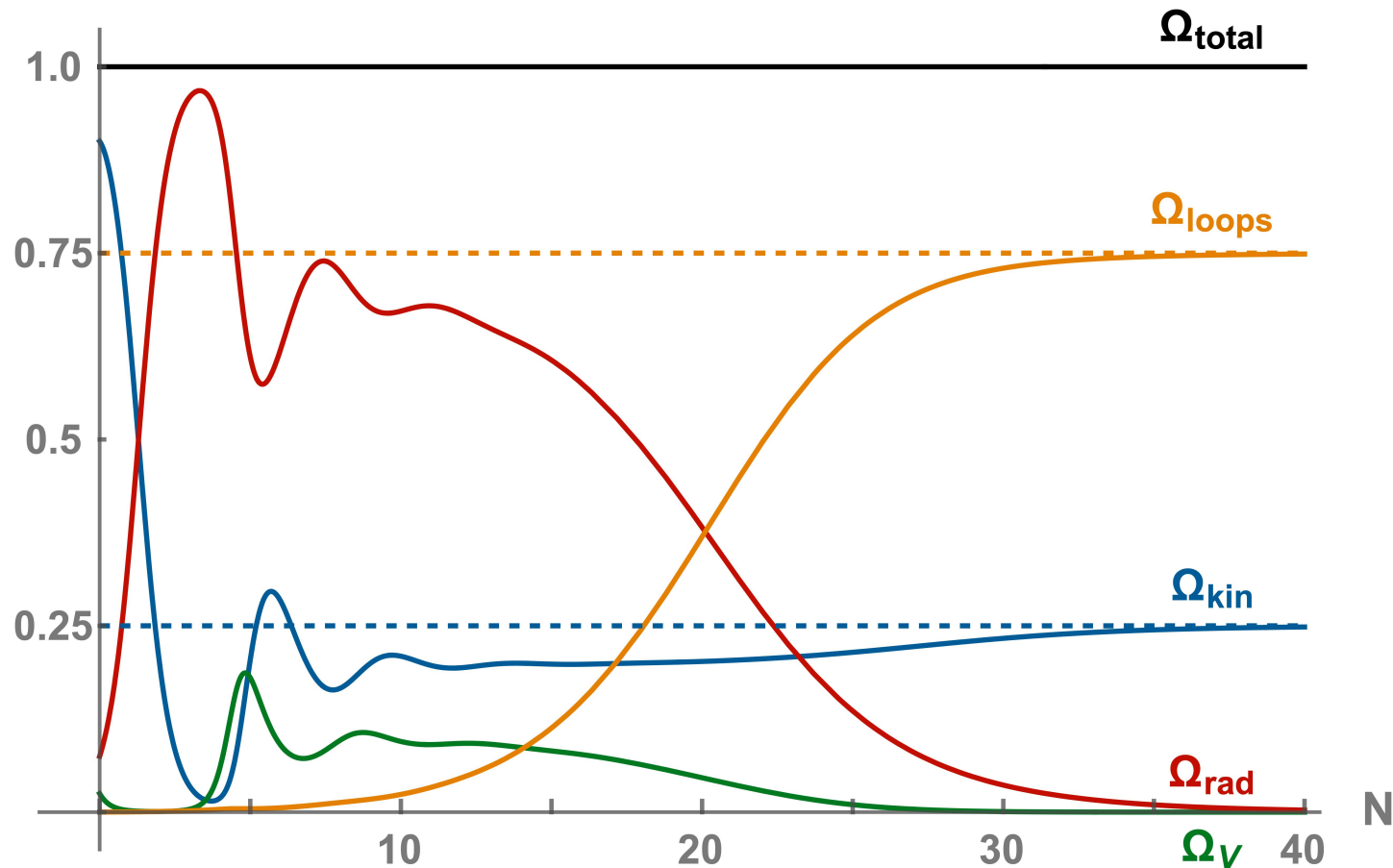
$$\Omega_{\text{kin}} = x^2$$

$$\Omega_V = y^2$$

$$\Omega_{\text{loops}} = z^2$$

# Dynamical system analysis

## Results: LVS and F-strings



**Fig. 2** Evolution of the energy fractions in time

# Conclusion

- **Early Universe + String Theory**
  - Moduli evolution
  - Cosmic strings with time-dependent tensions
  - Superstring phases



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... WHAT NEXT? *GWs as probes!*

