Topological Gravity as the Early Phase of our Universe

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With Prateek Agrawal, Sergei Gukov and Cumrun Vafa

Outline

- Motivation
  - Dualities
    - String Gas Cosmology
- Topological Scenario
- Phenomenology: Comparison With Inflation
- An Analogy With QCD

Motivation: Dualities

- Ubiquitous in string theory
- Essential when parameters are taken to extreme limits
- No effective theory is valid in all of parameter space
- New light modes appear in extreme limits

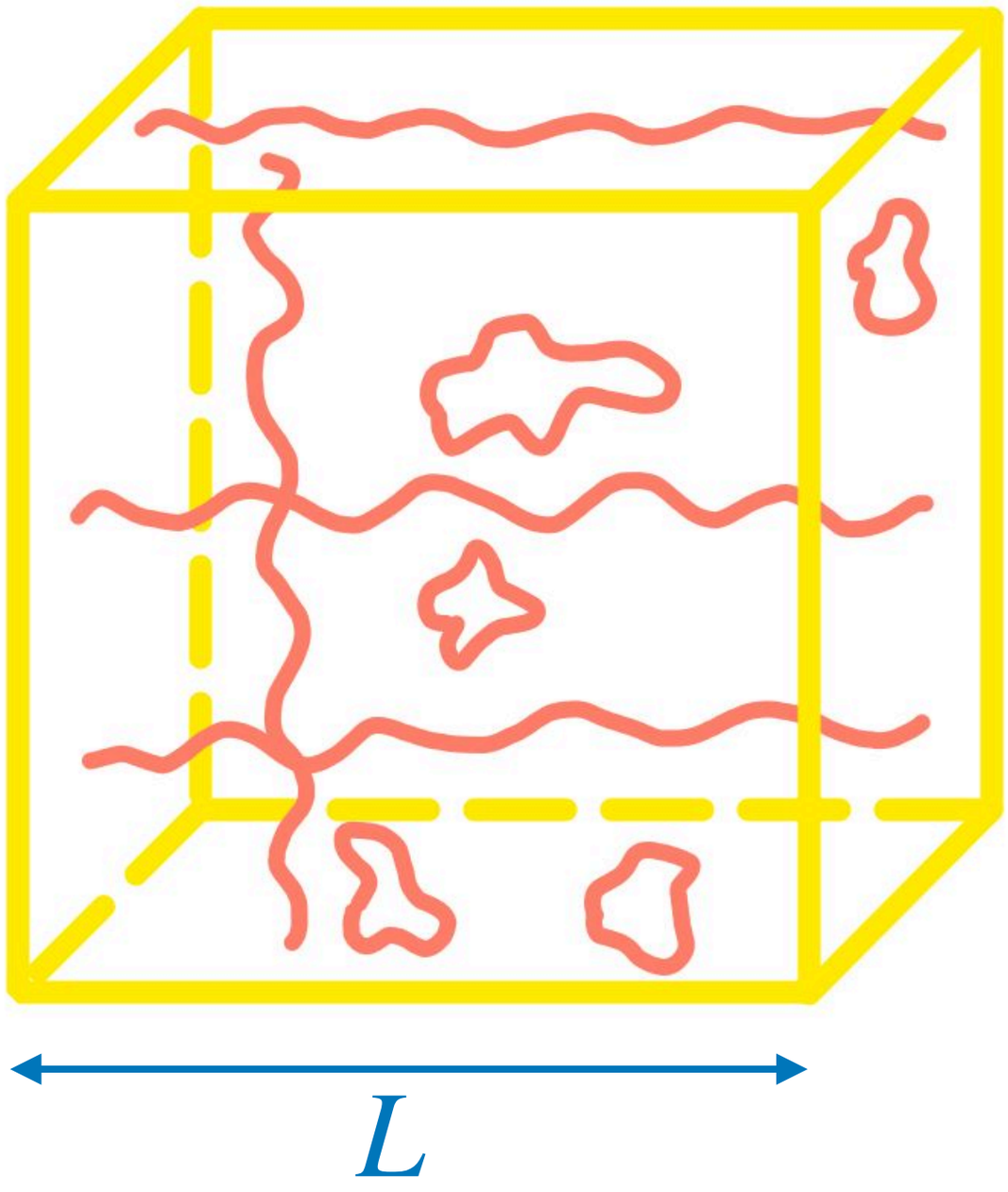
Early Universe is an extreme limit

$$T \to \infty, \quad a \to 0$$

Therefore:

It is natural to expect that there is a dual description for early universe

Motivation: String Gas Cosmology



[Brandenberger, Vafa ’89]
[Tseytlin, Vafa ’92] …

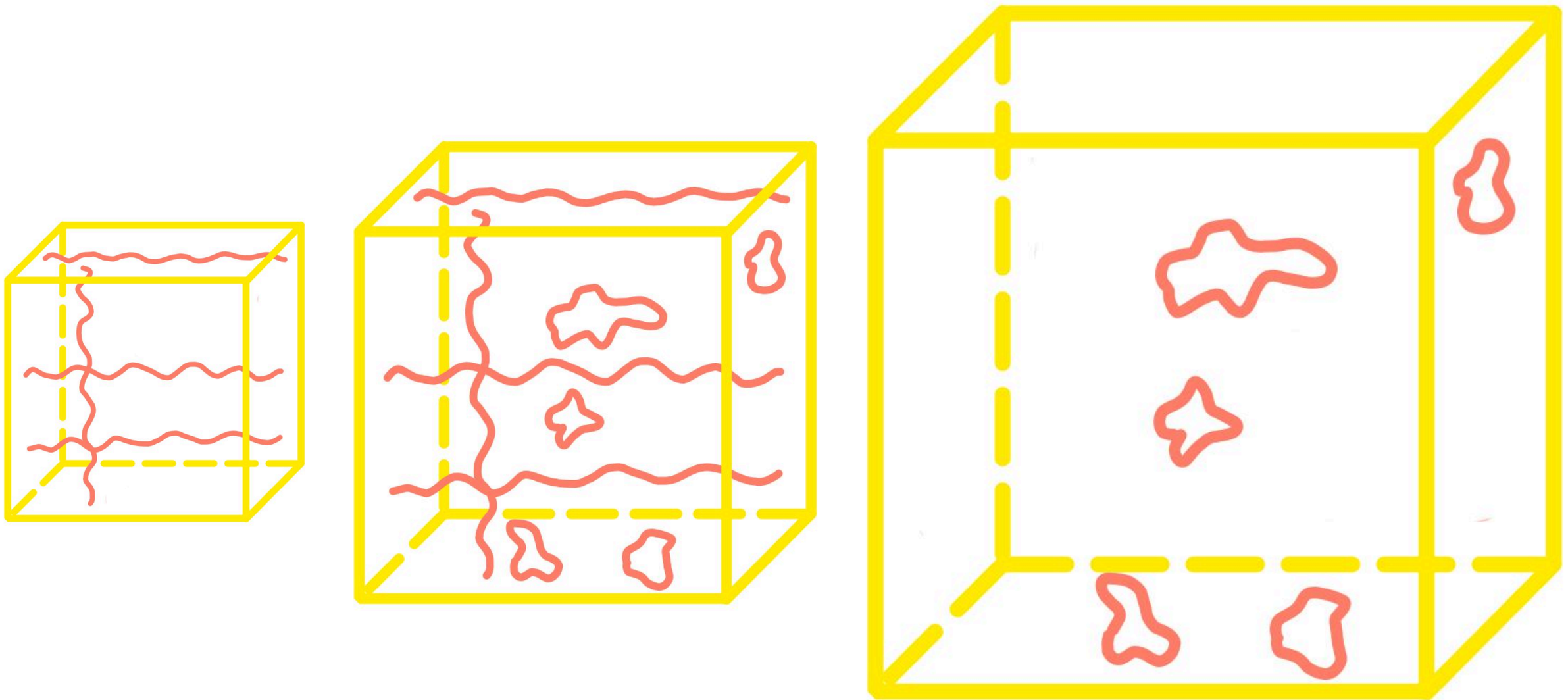
Motivated by T-duality:

$$p = n/L,\ w = mL$$

$$L \leftrightarrow 1/L,\ n \leftrightarrow m$$

$$|\tilde{x}\rangle = \sum_w e^{iw\tilde{x}} |w\rangle, \qquad |x\rangle = \sum_p e^{ipx} |p\rangle$$

Motivation: String Gas Cosmology

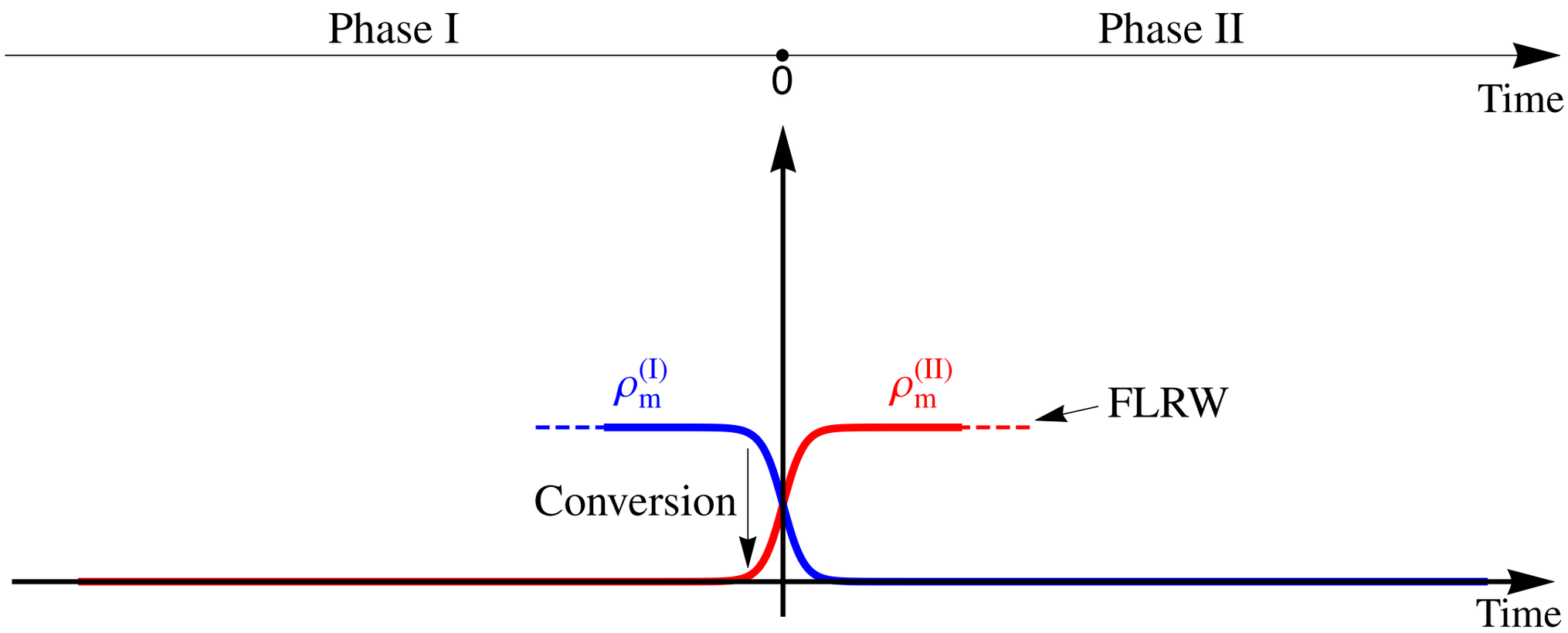


$$|\tilde{x}\rangle = \sum_w e^{iw\tilde{x}}|w\rangle, \qquad |x\rangle = \sum_p e^{ipx}|p\rangle$$

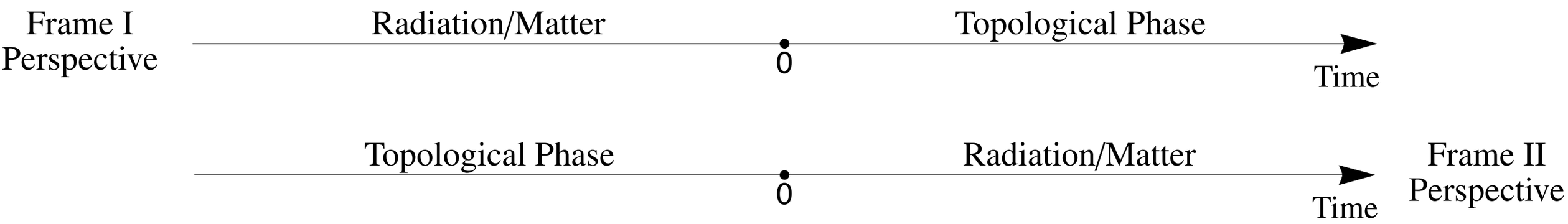
The early universe is x-independent (i.e. topological) from the point of view of the operators relevant today.

Duality in the Early Universe

- This holds more generally than in the T-duality
- Suppose we have two phases/frames (call them I and II)
- We do not know the nature of phase I but we know it is topological from our perspective

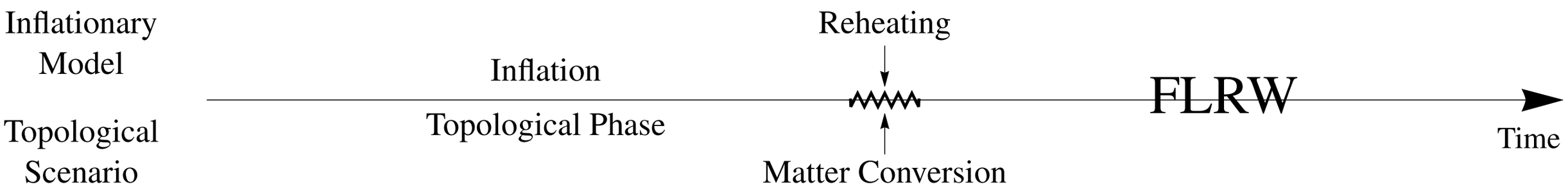


Topological Theory



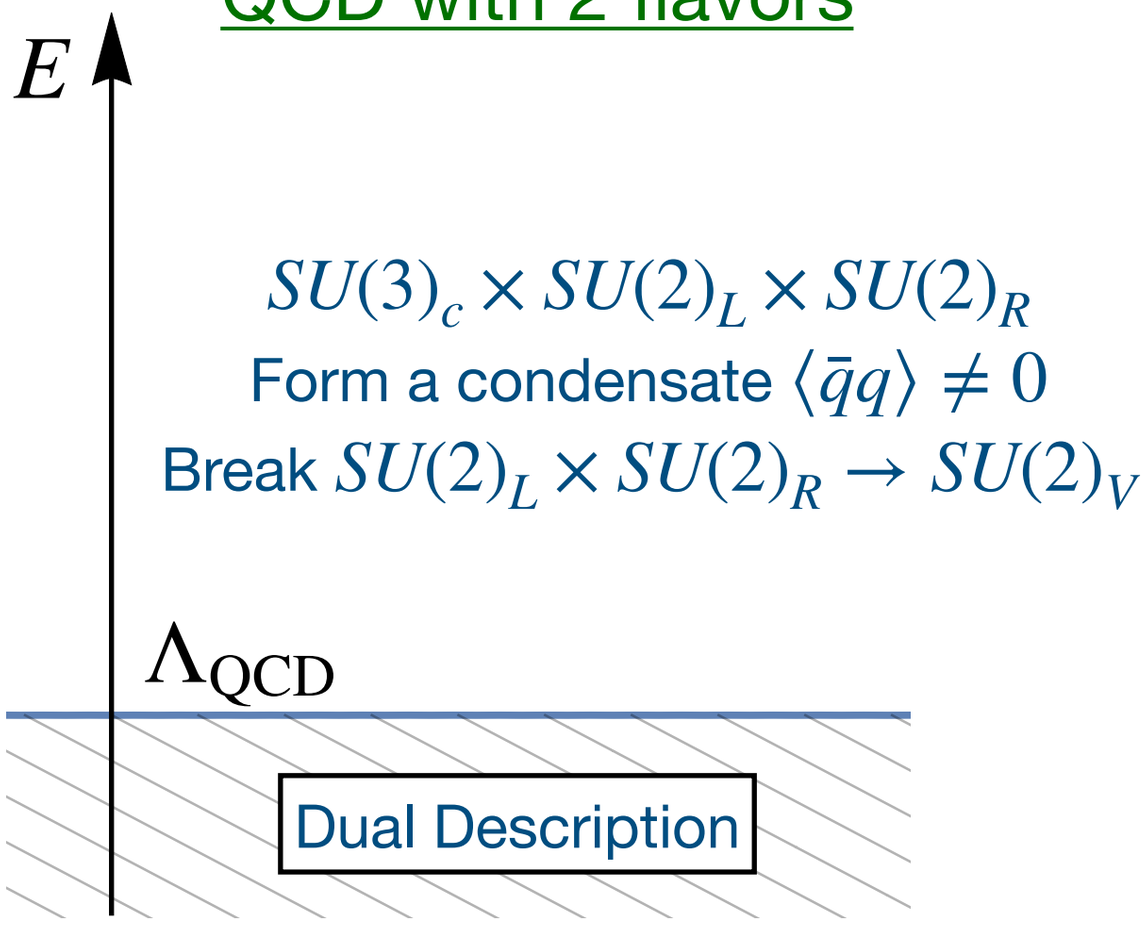
- Even gravity is topological since the graviton of phase I is different from the graviton of phase II
- Horizon problem (homogeneity) is automatically solved but because the topological theory is not sensitive to positions
- For other aspects we need to know more about the topological phase
- Consider Witten's 4d topological gravity as one realization [Witten '88]

Comparison with Inflation

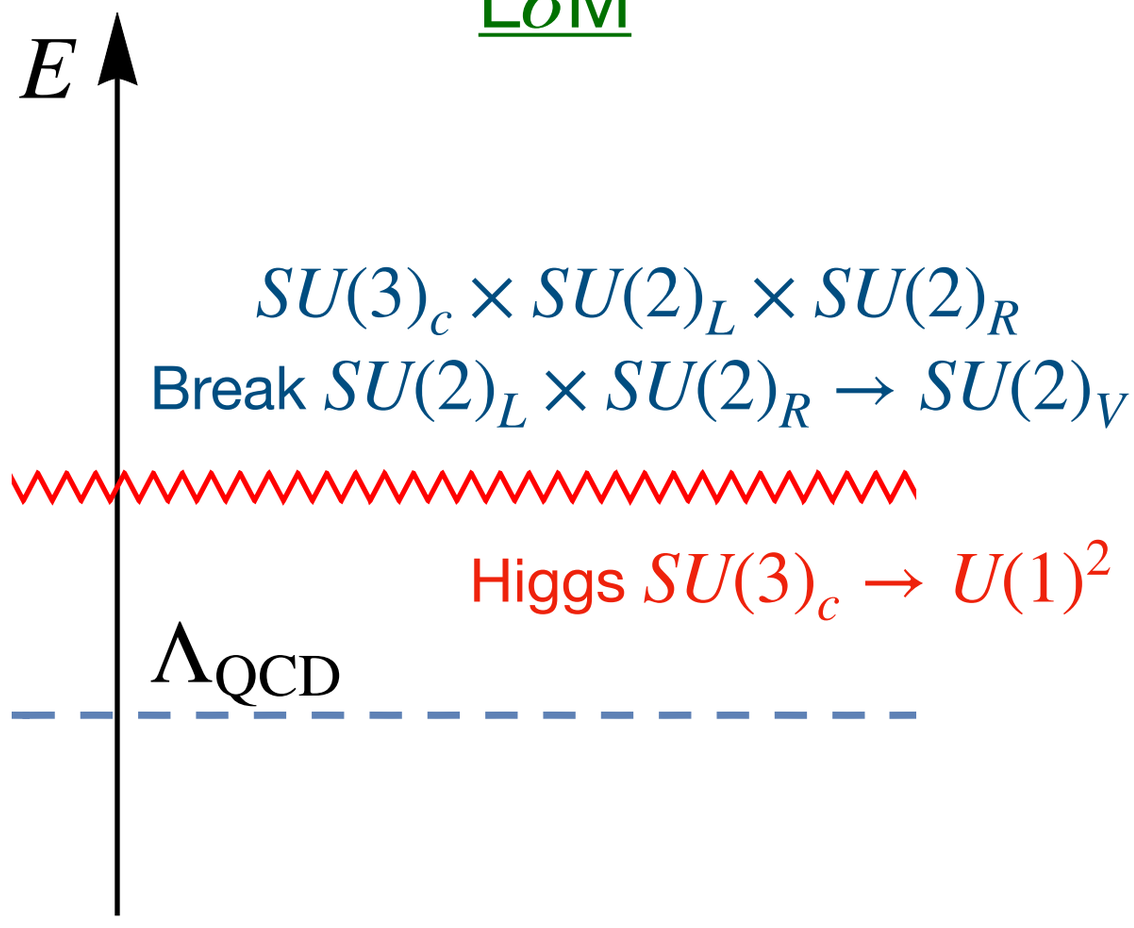


	Inflation	Topological Scenario
Homogeneity/Isotropy/ Flatness	dS bkg	Topological phase
(Near) Scale-inv.	(quasi-)dS bkg	(Weakly-broken) Topological phase
Red Tilt	Decreasing Hubble parameter	Positivity of conformal anomaly coefficient c (due to unitarity)
Non-Gauss.	$O(\epsilon)$ in simple models*	$O(1)$ for four- and higher-point functions*
Tensor modes	Present due to massless graviton	Absent since graviton is not dynamical in topological phase

Analogy with QCD: Particle Physics Side



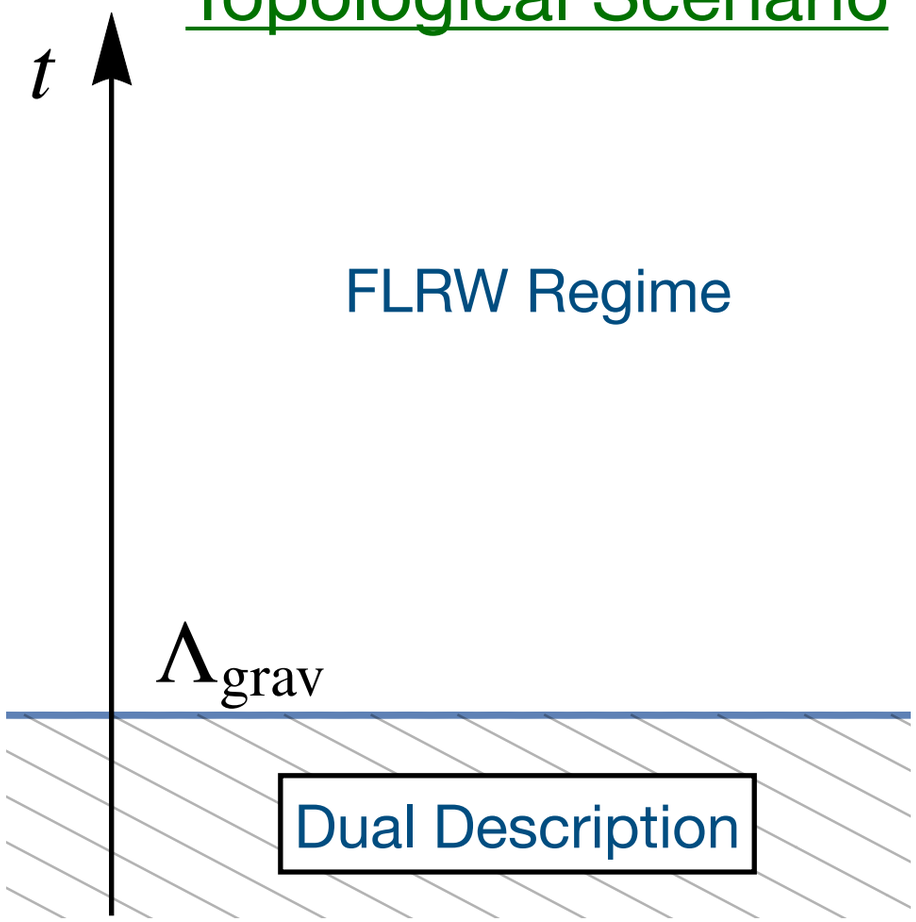
Low energy spectrum contains pions
No spin-1 gauge bosons



Low energy spectrum contains pions
2 spin-1 gauge bosons

Analogy with QCD: Cosmology Side

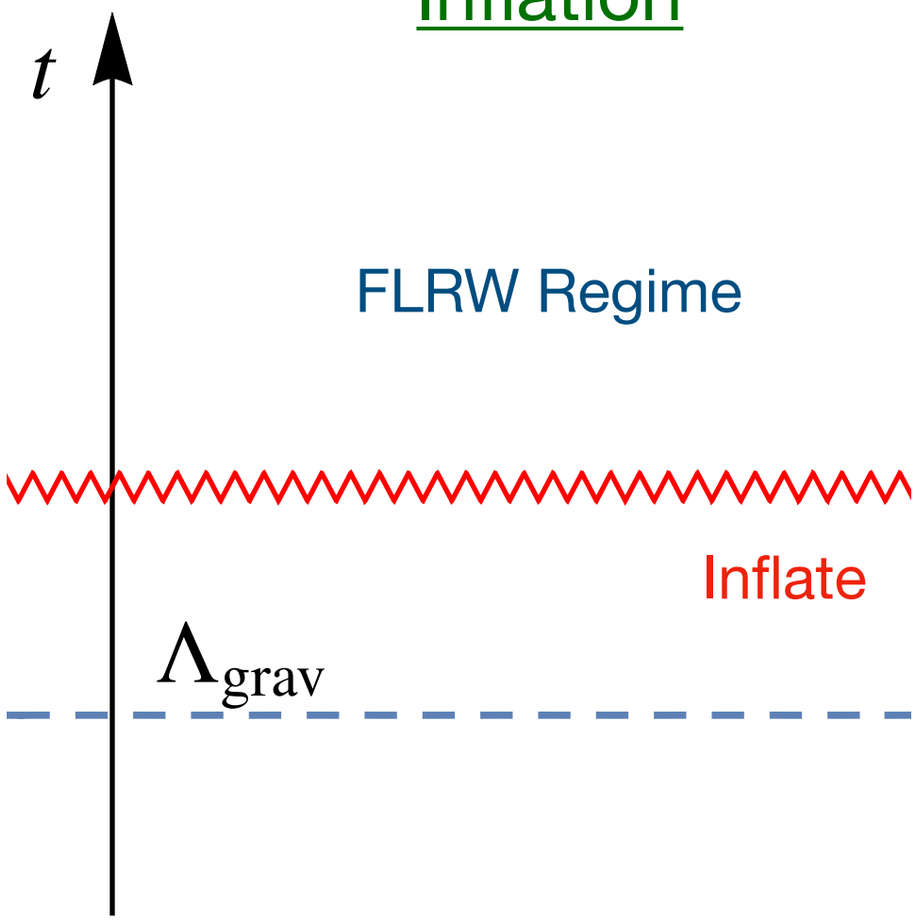
Topological Scenario



Additional sector gives a scalar mode

No graviton (no tensor modes)

Inflation



Inflaton gives scalar mode

Graviton present (tensor modes)

Symmetry breaking pattern dictates behavior of the scalar mode.

(cf. EFT of inflation)

[Cheung *et al.* ’08]

Conclusions

String theory dualities lead us to believe that the early universe is described by a dual theory

Early universe looks topological from our perspective; in particular it is not sensitive to our position variable

Taking Witten's 4d topological gravity as a realization, we addressed the puzzles of cosmology

Future directions:

- Other realizations of topological gravity in 4D
- Deeper understanding of the breaking of topological invariance
- Non-Gaussianities: develop tools to more systematically compute them.

Thank You!