Cosmological Inflation and Gauge/Gravity Duality

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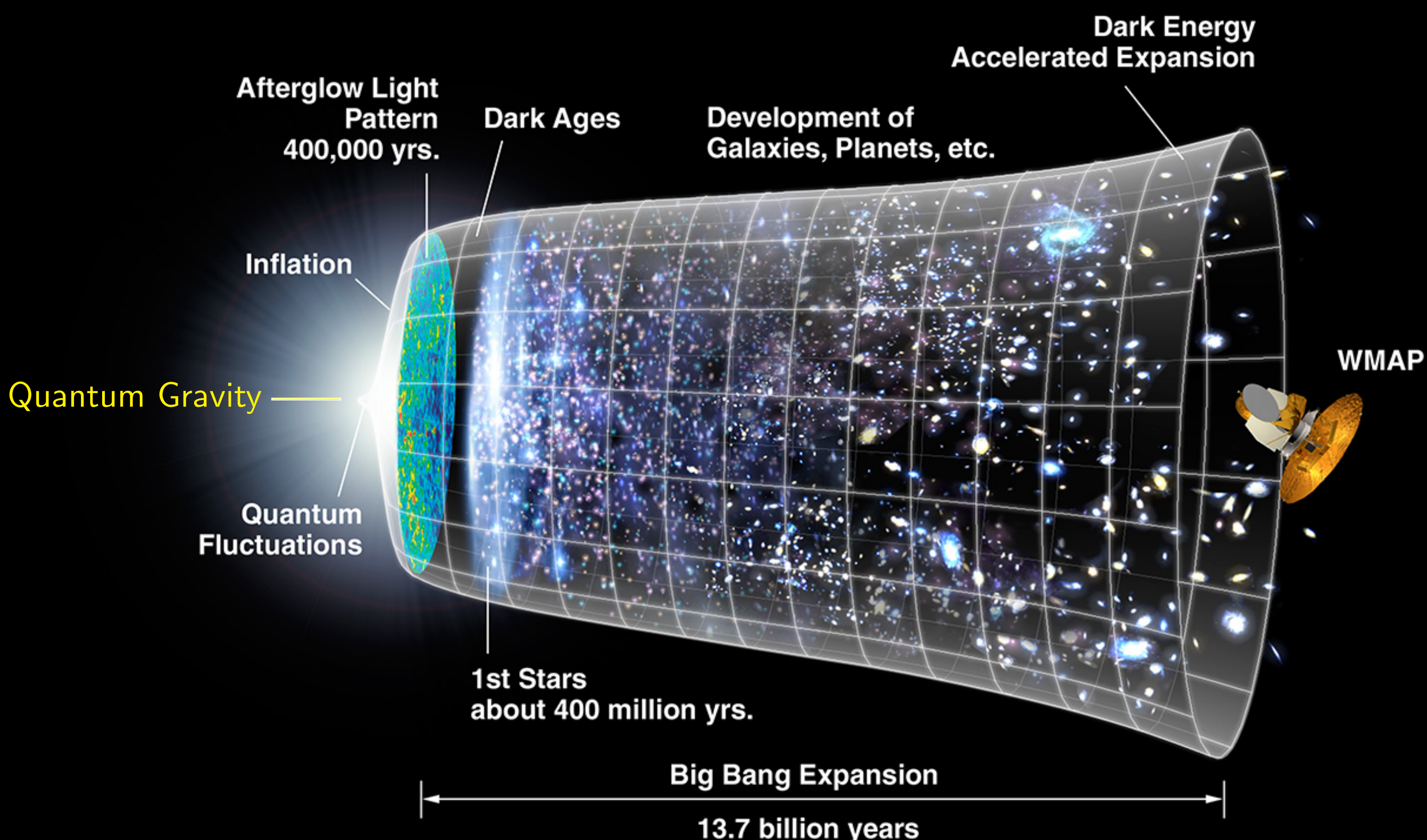
Inflation: Traces of Quantum Gravity ?



(Shortly after) Big Bang: Origin of all structure we see today!

NASA/WMAP Science Team

Cosmological Inflation:

Needed to solve several problems, chief among them being homogeneity and isotropy of the Universe on large scales

Inflationary expansion: driven by the potential energy of a scalar field (inflaton)

Standard description:

A weakly coupled Lagrangian for the inflaton within QFT framework

BUT: (after Planck satellite data, March, 2013)

There are important conceptual problems with that picture:

[A. Ijjasa, P. Steinhardt, A. Loeb, arXiv:1304.2785; arXiv:1402.6980]

– initial conditions problem $\left[\frac{1}{2}(\nabla\varphi)^2 \sim V(\varphi)\right]$

– "unlikeliness" problem

More recently:

BICEP2 data may indicate "large" gravitational waves (i.e. $r \approx 0.2$)

$\Rightarrow$ inflaton excursion $\sim \mathcal{O}(M_P)$ in field space

$\rightarrow$ beyond Effective Field Theory ?

Gauge/Gravity Duality

Nonperturbative method for studying strongly coupled gauge theories

Can build Inflationary models within the gravity duals of a class of strongly coupled gauged theories

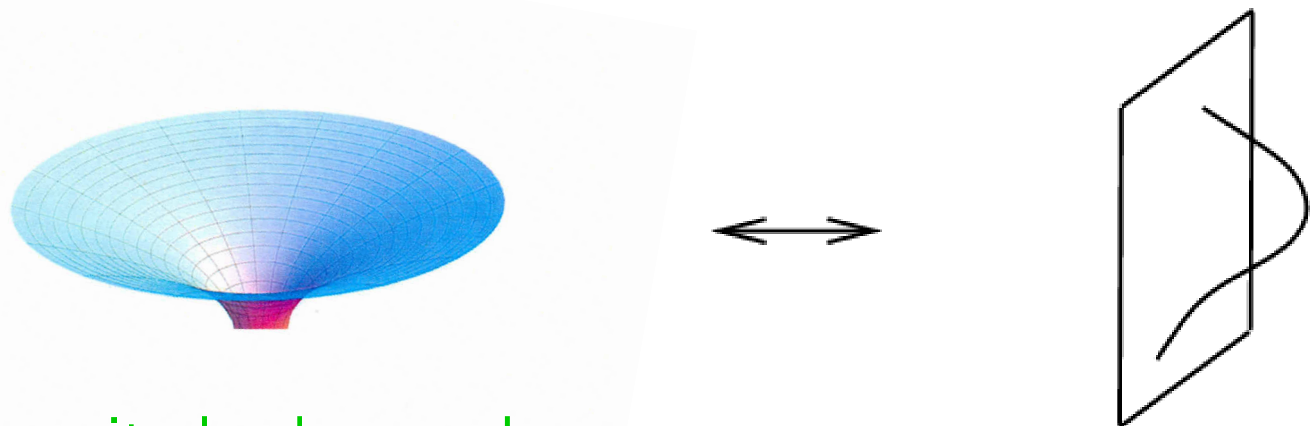
Is it possible to find in this class:

- models with large inflaton excursion [$\sim \mathcal{O}(M_P)$] ?
- solution to unlikeliness (etc.) problem(s) ?

Gauge/Gravity Duality

(AdS/CFT correspondence)

Two different perspectives on D-branes in string theory:



gravity background
[SUGRA solution]

open strings BCs
[gauge theory]

A stack of large number of D-branes:

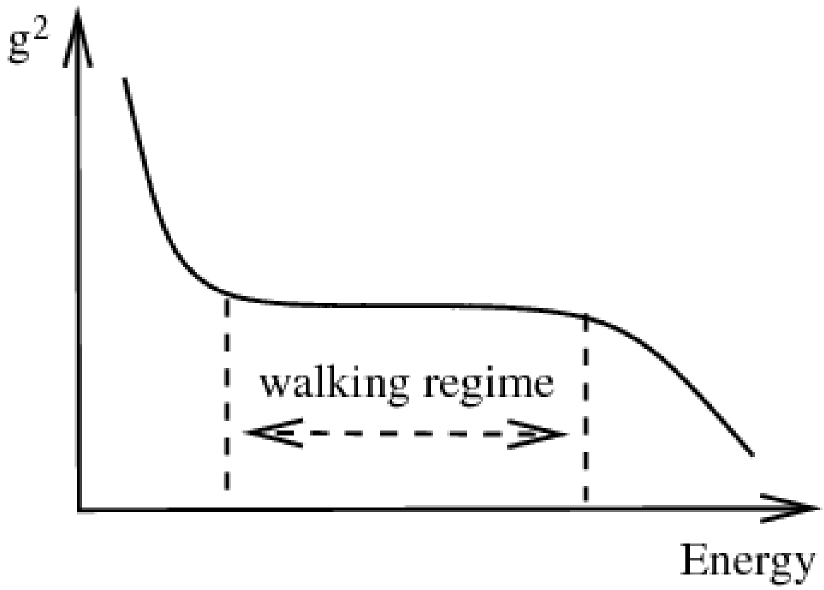
Two sides of duality encode same degrees of freedom

[The two sides have equal partition functions!]

Walking background:

[C. Nunez, I. Papadimitriou, M. Piai, arXiv:0812.3655]

Coupling of dual gauge theory:



Inflationary model:

probe D3 brane moving in walking region of gravity background

$\rightarrow$ has two dynamical scales

$\Rightarrow$ could allow overcoming the Lyth bound constraint

Lyth bound: (for FT description of inflation)

[D. Lyth, hep-th/9606387; S. Antusch, D. Nolde, arXiv:1404.1821]

$$\sqrt{r} < \mathcal{O}(10^{-1})\,\Delta\varphi$$, where $\Delta\varphi$ - inflaton excursion

$\Rightarrow$ If $\Delta\varphi < \mathcal{O}(M_P)$, then tensor to scalar ratio $r < 0.1$

(Recall: BICEP2 gives $r > 0.1$, although ?)

Lyth bound for D-brane inflation:

[Baumann, McAllister, hep-th/0610285]

Inflation: probe D3-brane moving in a nontrivial background sourced by N Dp-branes, where $N \gg 1$

$$\rightarrow \quad \Delta\varphi < \left(\frac{4}{N}\right)^{1/2} M_P \quad \Rightarrow \quad r \ll 0.1$$

Walking Inflationary model:

Two dynamical scales $\quad \rightarrow \quad$ two parameters c, α

Bound: $\quad \Delta\varphi < f(c,\alpha)\, M_P$

$\rightarrow$ In principle: Possible to find region(s) of parameter space, where $\Delta\varphi$ is large enough to have $r > 0.1$

- In practice: Work in progress...

  [Difficulty: Walking solution only known in certain limit, which is not suitable. Need to explore other regions of parameter space.]

Unlikeliness problem: (Steinhardt et al.)

Can build inflationary models ("slow-walking" inflation) with $r \ll 1$:

D3 probe in walking region of known limit solution

[J. Erdmenger, S. Halter, C. Nunez, G. Tasinato, arXiv:1210.4179]

In this class of models:

– Form of inflaton potential $\Rightarrow$ no "unlikeliness problem"

– Initial conditions problem also automatically solved

[walking region $\rightarrow$ very slow roll due to a very flat potential

$\Rightarrow \frac{1}{2}(\nabla\varphi)^2 \ll V(\varphi)$]

Summary

New observational data:

- Restrict set of viable inflationary models
- Lead to a variety of problems

  [unlikeliness, initial conditions, too small r]

New class of models from walking backgrounds:

- Could avoid unlikeliness, initial conditions problems
- Could provide $\Delta\varphi \gtrsim M_P$ and thus $r > 0.1$

But still work to do...

Thank you!