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:


– initial conditions problem \[ \frac{1}{2} (\nabla \varphi)^2 \sim V(\varphi) \]
– “unlikeness” problem

More recently:

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

\[ \Rightarrow \text{inflaton excursion} \sim \mathcal{O}(M_P) \text{ in field space} \]

\[ \rightarrow \text{beyond Effective Field Theory?} \]
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 \([\sim O(M_P)]\) ?

– 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:


Coupling of dual gauge theory:

Inflationary model:

probe D3 brane moving in walking region of gravity background

→ has two dynamical scales

⇒ could allow overcoming the Lyth bound constraint
Lyth bound: (for FT description of inflation)

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

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

(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 \( N \) D\(_p\)-branes, where \( N \gg 1 \)

\[ \Rightarrow \Delta \varphi < \left( \frac{4}{N} \right)^{1/2} M_P \Rightarrow r \ll 0.1 \]
Walking Inflationary model:

Two dynamical scales $\rightarrow$ two parameters $c, \alpha$

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

$\rightarrow$ 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


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

\[ \Rightarrow \frac{1}{2}(\nabla \phi)^2 \ll V(\phi) \] ]
Summary

New observational data:

• Restrict set of viable inflationary models
• Lead to a variety of problems
  [unlikeness, initial conditions, too small $r$]

New class of models from walking backgrounds:

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

But still work to do...
Thank you!