Signatures of Modulations in Axion Monodromy Inflation

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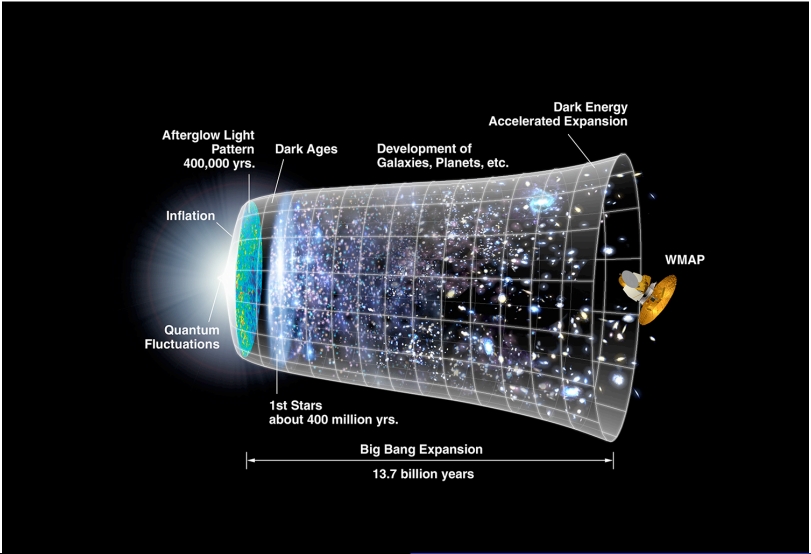
work in progress with R.Flauger L.McAllister E.Pajer E.Silverstein A.Westphal

December 9, 2008

Outline

Inflation


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

Brief Introduction to Inflation

A period of accelerated expansion

$$ds^2 = -dt^2 + e^{2Ht} d\vec{x}^2 \qquad H \approx const$$

Explains why universe is so large, flat and empty (Guth, 1981)

Predictions:

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- Tensor fluctuations $r = 16\epsilon$, where $\epsilon \equiv -\frac{\dot{H}}{H^2}$.
- Scalar fluctuations are approximately Gaussian.

Why non-Gaussianity?

- $\phi = \phi_G + f_{NL}\,\phi_G^2$ [1]

[1] WMAP5 Komatsu et.al arXiv: 0803.0547[astro-ph]

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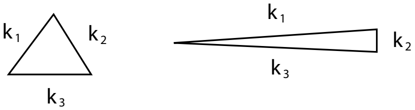

Equilateral **Local**

- WMAP5 data gives: $-9 < f_{NL}^{local} < 111$ [1]
  $-151 < f_{NL}^{equil} < 253$ [1]
- Would be a truly remarkable discovery

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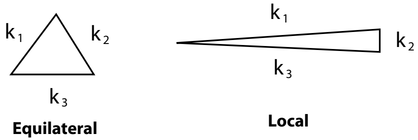

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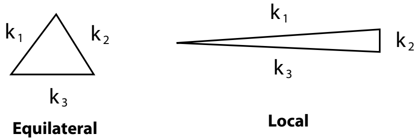

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- Let's hope we are lucky!

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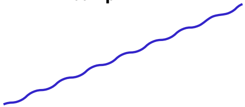
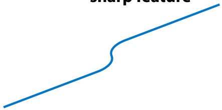
Current Situation

- Generic single field slow roll: $f_{NL} \sim O(\epsilon), \quad \epsilon \sim 10^{-2}$
- Exceptions: non-inflation models, DBI inflation or

bump



sharp feature



- For a potential with oscillatory modulations, when $H < \omega < M_p$ the non-Gaussianity will be dominated by [2]

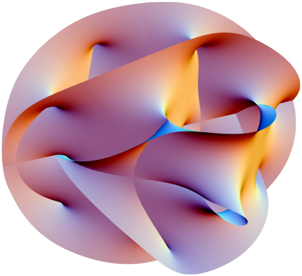
$$f_{res} \sim \epsilon\dot{\eta} \qquad \eta \equiv \frac{\dot{\epsilon}}{\epsilon H}$$

[2] Chen, Easther, and Lim arXiv:0801.3295[astro-ph]

Motivation Summary

- **Inflation** can deliver a flat, homogeneous universe.
- **Non-Gaussianity** can tell us a lot about this inflationary era.
- A **resonant production mechanism** can help us to achieve an observable non-Gaussianity.

Why string theory?



- Promising candidate for UV completion
- Easy to find a scalar to act as the inflaton

Why axions?

Axion: a pseudo-Goldstone boson with a shift symmetry,

$$S(a) = S(a + f),$$

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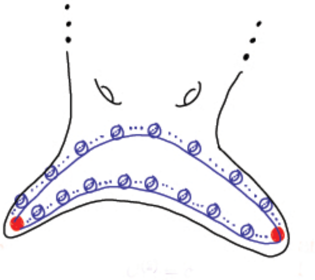

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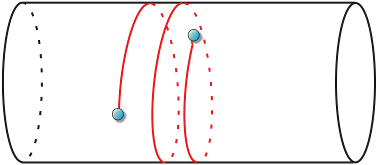

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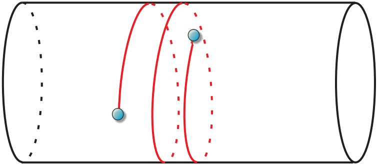

$$S_{DBI} = -\int \frac{d^{p+1}\xi}{(2\pi)^p} \alpha'^{-(p+1)/2} e^{-\Phi} \sqrt{det(G_{MN} + B_{MN})\partial_\alpha X^M \partial_\beta X^N}$$

$$V(b) = \frac{\epsilon}{g_s (2\pi)^5 \alpha'^2} \sqrt{l^4 + b^2}$$

Large field inflation: $V(\phi) \approx \mu^3 \phi$

Parameter Fixing

Potential

$$V = \mu^3\phi + \Lambda^4 \cos\left(\frac{\phi}{f}\right)$$

- 60 e-folds: $\phi_0 \approx 11 M_{pl}$
- COBE: $\mu = 6 \times 10^{-4} M_{pl}$
- CMB: $\frac{\Lambda^4}{\mu^3} < 3.3 \times 10^{-4} M_{pl}$

Calculation steps and Predictions

1. **Background evolution:** solve $\ddot{\phi} + 3H\dot{\phi} + V'(\phi) = 0$
2. **Calculate spectrum:** solve Mukhanov-Sasaki equation

$$u_k'' + (k^2 - \frac{z''}{z}) = 0, \qquad z \equiv \frac{a\dot{\phi}}{H}$$

3. **Calculate bispectrum:** following Chen *et al.*

Predictions

$n_s \approx 0.975$ and $r \approx 0.07$

f the decay constant

Prediction

$$f_{res} \simeq \frac{9\Lambda^4}{4\mu^3\phi_0^{3/2} f^{5/2}},$$

Where $f = \frac{c_0}{2\pi}\sqrt{\frac{g_s}{T_L}}$ [4], and $f_{res} \simeq 2 \times 10^{-3} \left(\frac{T_L}{c_0^2 g_s}\right)^{5/4}$

[4] Svrcek and Witten[arXiv:hep-th/0605206]

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4. Taste bound: $N_L < 50$

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Table of Results

T_L	N_L	g_s	f_{res}
30	40	0.03	11
26	33	0.05	5
15	17	0.1	1

Conclusion

We have studied the observational signatures of an axion monodromy inflation model. This model predicts observable non-Gaussianity.