Non-Gaussianities in Multifield Inflation

Superhorizon Evolution, Adiabaticity, and the Fate of f_{NL}

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Outline

Non-Gaussianities in Single Field Inflation

- $f_{NL}^{\rm local}$ is always small in single field inflation.
- The single field consistency relation gives

$$f_{NL}^{\rm local} = \frac{5}{12}(1 - n_S)\,.$$

- A convincing detection of $f_{NL}^{\rm local}$ would rule out all models of single field inflation.

Maldacena (2002); Creminelli, Zaldarriaga (2004); Ganc, Komatsu (2010); Renaux-Petel (2010)

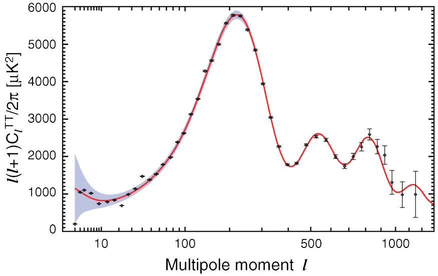
Circumventing the Consistency Relation

- Models with multiple dynamical fields are not subject to the consistency relation.
- The curvature perturbation can evolve outside the horizon in the presence of multiple dynamical fields.
- Several models producing large non-gaussianities by the superhorizon evolution of the curvature perturbation have been proposed.
  - Multiple field inflation
  - Modulated reheating
  - Curvaton

Byrnes, Choi, Hall (2008); Zaldarriaga (2003); Lyth, Ungarelli, Wands (2003)

Adiabatic Modes

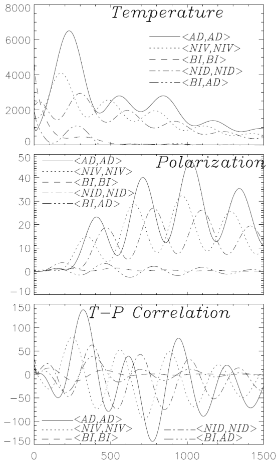
- There always exists an adiabatic solution of the equations governing cosmological perturbations.
- The curvature perturbation is conserved outside the horizon in the adiabatic solution.
- Single field inflation always produces adiabatic fluctuations.



Weinberg (2003), (2008a), (2004a); WMAP Science Team

Non-Adiabaticity and Observation

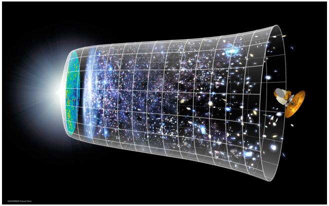
- Fluctuations in the presence of multiple fields are generally non-adiabatic.
- Non-adiabaticities which persist through the radiation-dominated era produce observable effects on the CMB.
- Observations have not detected any evidence for non-adiabtic fluctuations.
  - Uncorrelated $\alpha_0 < 0.077$
  - Anticorrelated $\alpha_{-1} < 0.0047$



Bucher, Moodley, Turok (2001); Komatsu, et. al. (2010)

Non-Adiabaticity and Non-Conservation

- The curvature perturbation is not conserved in the presence of non-adiabatic fluctuations.
- To make sharp predictions, the evolution of the curvature perturbation must be calculated until it becomes conserved, or until it is observed.
- If the cosmological fluctuations do not become adiabatic, predictivity requires knowledge of the entire history of the universe stretching back to inflation.



NASA/WMAP Science Team

Approach to Adiabaticity

- There are at least two ways that non-adiabatic fluctuations can become adiabatic:

- Single field inflation

- Local thermal equilibrium with no non-zero conserved quantum numbers

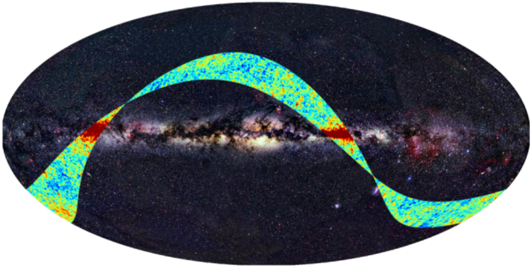
Weinberg (2004b), (2008a), (2008b)

Superhorizon Evolution and Non-Gaussianities

Any model which generates large non-gaussianity by the superhorizon evolution of the curvature perturbation is incomplete without an understanding of the evolution of the cosmological perturbations until they become adiabatic, or until they are observed.

Planck

- Data from the Planck satellite will further constrain both non-adiabaticity and non-gaussianity.
  - Non-adiabaticity constraints will improve by an order of magnitude
  - Projected constraints on non-gaussainity: $\Delta f_{NL}^{local} \sim 5$



Komatsu, Spergel (2001); ESA/Planck Science Team (2010)

Two Field Inflation

- Do there exist models of multiple field inflation which produce large $f_{NL}^{\rm local}$ and a purely adiabatic power spectrum?
- We study a class of two field models which pass through an effectively single field phase before inflation ends.
- We only require a few e-folds of inflation where all but one of the eigenvalues of the mass matrix are large and positive in order to damp away non-adiabatic fluctuations.

The Model

- We use the δN formalism to calculate two- and three-point statistics in two field inflation.
- We study potentials of the form $W(\phi, \chi) = F(U(\phi) + V(\chi))$.
- To calculate f_{NL}^{local} we use the formula

$$\frac{6}{5} f_{NL}^{(4)} = \frac{\sum_{IJ} N_{,I} N_{,J} N_{,IJ}}{\left(\sum_K N_{,K}^2\right)^2} .$$

Sasaki, Stewart (1996); Lyth, Rodriguez (2005)

Results

- Barring some fine tuning, we find

$$\frac{6}{5} f_{NL}^{(4)} \sim \mathcal{O}(\epsilon_*) + \mathcal{O}(1) \times \frac{\epsilon_c^{\phi}\epsilon_c^{\chi}}{\epsilon_c^2}\eta_c^{ss} \,,$$

where η^{ss} is related to the mass of non-adiabatic fluctuations

$$\eta^{ss} \equiv \frac{\epsilon^{\chi}\eta^{\phi} - 2\sqrt{\epsilon^{\phi}\epsilon^{\chi}}\eta^{\phi\chi} + \epsilon^{\phi}\eta^{\chi}}{\epsilon} \,.$$

Gordon, Wands, Bassett, Maartens (2001); JM, Sivanandam (2010)

Results

- When the non-adibatic fluctuations become heavy compared to the Hubble rate ($\eta_{ss} > 1$), we find:

$$|\delta s| \sim \mathrm{Exp}\left[-\frac{3}{2}\int H \mathrm{d}t\right]$$

$$f_{NL}^{(4)} \sim \mathcal{O}(\varepsilon_*) + \mathcal{O}(1) \times \eta^{ss}\mathrm{Exp}\left[-2\int C_\eta H \eta^{ss} \mathrm{d}t\right]$$

where C_η is a number which is always greater than 1.

JM, Sivanandam (2010)

Conclusions

- The superhorizon evolution of the curvature perturbation may be able to produce large non-gaussianity.
- The evolution of the curvature perturbation must be understood until the time of conservation or observation.
- f_{NL}^{local} is damped faster than non-adiabatic fluctuations when isocurvature modes become heavy in two field inflation.

On the Horizon

- More general class of potentials
- More than two fields
- Thermal equilibrium