Primordial non-Gaussianity: Theory Confronts Observations (Closing thoughts)

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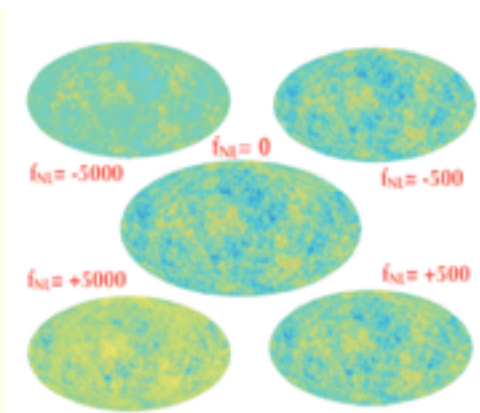
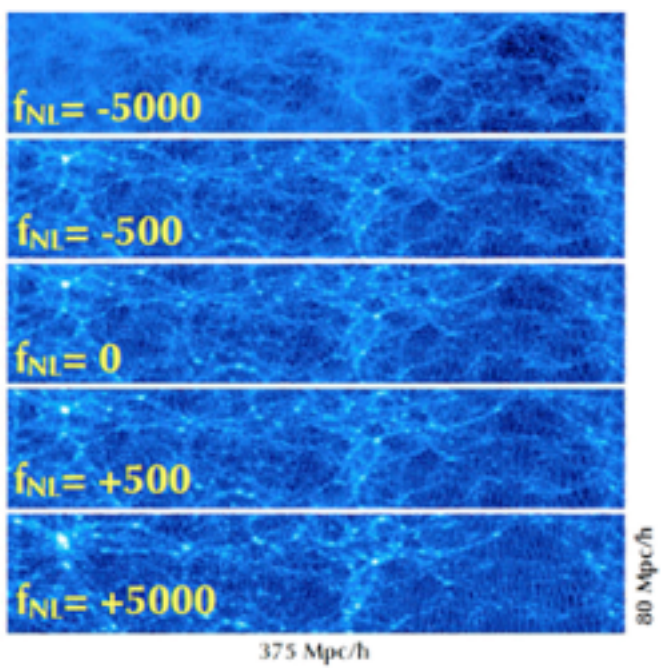




Acknowledgments

Reminder: Have Dragan take me down if I get out of hand.

Observations **(clearly progress)**

- New Shape Independent Methods (Cambridge group -- Modal Methods)
  Advantage: No theoretical bias
  However, Some models missed? (e.g. Flauger, Leblond, and Pajer, ...?)

- Large Scale Structure as test of Non-Gaussianity
  (Largely ignored by **some of the** theoretical community?)

    - Scale Dependent Bias (many, many speakers)
      Challenge: Realize $f_{NL}(k)$ in fundamental theory?
      Challenge: Be careful with gauge dependent effects: (Jeong and Yoo)

- Sky brightness and contamination removal (Shirley Ho's talk)

- Consistency condition for multi-field (Komatsu)

Need some data!

Fundamental Theory

Primordial non-Gaussianity:
Theory Confronts Observations

?

Phenomenological Approaches (Bottom-Up): (Agullo, Ashoorioon, Adshead, Barnaby, Chen, Chung, Ganc, Koyama, Kumar, Meyers, Peloso, Tanaka, Yokoyama)

Feature --> Theory

Advantage: Connection to observations. Identify interesting signatures.

Challenge:
Anything goes.
Constrain all parameters by experiment-- very hard (impossible?)
Past lessons: Reconstruction of inflaton potential, transplanckia
Models are UV sensitive!

Top-Down Model Building: (Flauger, Leblond, Pajer, and many others not here)

Theory --> Feature

Advantage: Existence proofs. Rigid constraints. Theoretical self consistency.
Inflation is UV sensitive -- many models ruled out for cost of a theorist.

Challenge: Very specific parameters -- robustness?

Particle Physics Inspiration: EFT Methods

Top-Down Model Building (Symmetries)

+

Phenomenological Approaches (Data)

The Effective Field Theory

Inflation: Quasi dS phase with a broken time-translation.

(Creminelli, D'Amico,Senatore, Shiu)

Inflation: theory of the Goldstone. $\pi \rightarrow \pi - \delta t$

$$S_\pi = \int d^4x \sqrt{-g} \left[M_{\rm Pl}^2 \dot{H} (\dot{\pi}^2 - (\partial_i \pi)^2) + M_2^4 \left(\dot{\pi}^2 + \dot{\pi}^3 - \dot{\pi} (\partial_i \pi)^2 \right) - M_3^4 \dot{\pi}^3 + \dots \right]$$

- Analogous of the (more important!) Chiral Lagrangian for the Pions S.Weinberg **PRL 17, 1966** $\pi \sim \delta\phi$
- All single field models are unified (Ghost Inflation, DBI inflation, ...); prove theorems:
  - Theorem: In single clock models, only Inflation can produce more than 10 e-foldings of scale invariant fluct.

with Baumann and Zaldarriaga **1101:3320** [hep-th]

- What is forced by symmetries and large signatures are explicit:
  - The spatial kinetic term: pathologies for : $\dot{H} > 0$ add $\delta E^2 \Rightarrow (\partial_i^2 \pi)^2 \Rightarrow w < -1$

with Creminelli, Luty and Nicolis, **JHEP 0612**

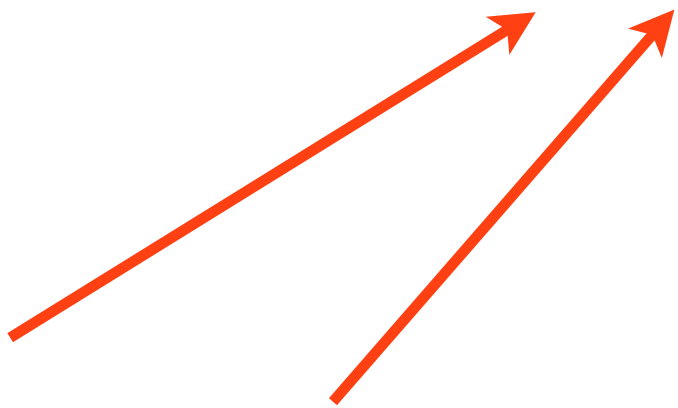
  - Connection between c_S and Non-Gaussianities: $\dot{\pi}^2 - c_s^2 (\partial_i \pi)^2$,

NG: $f_{\rm NL}^{\rm non-loc.} \sim \frac{1}{c_s^2}$

- Large interactions are allowed $\Longrightarrow$ Large non-Gaussianities! $\dot{\pi}(\nabla\pi)^2$ $\dot{\pi}^3$

Effective Field Theory in Cosmology

$$S_\pi = \int d^4x\, \sqrt{-g} \left[M_{\rm Pl}^2 \dot{H} (\dot{\pi}^2 - (\partial_i \pi)^2) + M_2^4 \left(\dot{\pi}^2 + \dot{\pi}^3 - \dot{\pi} (\partial_i \pi)^2 \right) - M_3^4 \dot{\pi}^3 + \dots \right]$$



Some related by UV symmetry (e.g. sound speed and leading NG)

Eliminate unknowns

Input from experiment

Eliminate unknowns

Challenges

Analogy to physics beyond the Standard Model (in fact, striking analogy -- eta problem)

$$V(H) = m^2|H|^2 + \lambda|H|^4 + \kappa|H|^6$$

UV Issues:

Hierarchy problem, Gauge Coupling Unification

IR Issues:

Must reproduce Electro-weak precision data and symmetries of Standard Model

What symmetries in (UV/IR) to impose for Inflation?

Effective Field Theory Approach

Challenges (lots to do):

- UV and IR constraints to impose?

- Beyond EFT of inflation (different backgrounds)
  - Pre-inflation?
  - (p)reheating?
  - Other phases?
  - Alternatives to inflation? (e.g. Khoury)
  - Multi-field? (isocurvature after inflation?)

- When EFT fails (e.g. Barnaby, Chung, Flauger, Leblond, Pajer, Shiu)
  - Rapid oscillations -- Non-adiabaticity?
  - Excited vacuum?
  - Are these cases interesting or exotic physics?

    (e.g. Transplanckian effects from fundamental theory are not observable in 2pt)

Could it be that with all the data in, we still can not reconstruct the fundamental Lagrangian?

(recall “reconstructing the inflationary potential”)

Best Strategy:

Develop EFT methods for Cosmology further?

Thank you everyone for coming
and making it a great workshop!