Cornell University
Department of Astronomy

GENERAL SINGLE FIELD INFLATION

NISHANT AGARWAL
RACHEL BEAN

APS APRIL MEETING, DENVER
MAY 2-5, 2009
T8.2

N. Agarwal and R. Bean, Phys. Rev. D 79, 023503 (2009), arXiv: 0809.2798

Outline

- Introduction
  - Inflation
  - Observational constraints
  - Action reconstruction
- The Hubble flow formalism
- Primordial perturbations
- Observable predictions of inflation
  - Monte Carlo simulations of inflationary trajectories
  - Constraints from cosmological observational data
- Summary and Discussion

Introduction

1. Inflation

- Rapid expansion of the early universe
- Solves horizon problem, flatness problem, structure formation, density of magnetic monopoles
- Lacks a firm physical basis
- Will provide an understanding of particle physics at high energies, maybe string theory

2. Observational constraints

- Data from CMB anisotropies and Large scale structure surveys characterize the primordial power spectrum to fine detail
- Reconstruct underlying theory from data
- DBI inflation, k-inflation
- Entire inflaton action instead of just the potential or a specific kinetic term

- *H. Peiris and R. Easther, JCAP 0607, 002 (2006), astro-ph/0603587*
- *B.A. Powell and W.H. Kinney, JCAP 0708, 006 (2007), arXiv: 0706.1982*
- *J. Lesgourgues, A.A. Starobinsky, and W. Valkenburg, JCAP 0801, 010 (2008), arXiv: 0710.1630*

3. Action reconstruction

- Include possibility of non-minimal kinetic terms
- Can produce large non-Gaussian behaviour for curvature perturbations
- General Lagrangian, $\mathcal{L}(X, \phi)$, of a single scalar field ϕ, with $X = \frac{1}{2}\partial_\mu \phi \partial^\mu \phi$
- In the usual formalism, $n_s(k)$ can be used to reconstruct $V(\phi)$ on fixing a reheating scenario
- Now $n_s(k)$ and other observables reconstruct properties of the action as a whole (not just $V(\phi)$).

- *R. Bean, D.J.H. Chung, and G. Geshnizjani, Phys. Rev. D 78, 023517 (2008), arXiv: 0801.0742*

The Hubble flow formalism

- Taylor expansion in $H, \mathcal{L}$, and c_s
- Evolution of H and c_s can be written as an infinite hierarchy of *flow parameters.*
- For the specific scalar field choice $\mathcal{L}_X = c_s^{-1}$,

$$\epsilon \equiv -\frac{\dot{H}}{H^2}, \qquad \eta \equiv \frac{\dot{\epsilon}}{H\epsilon}, \qquad \kappa \equiv -\frac{(\dot{c_s^{-1}})}{H(c_s^{-1})},$$

$$
\begin{aligned}
{}^l\lambda(\phi) &= \left(\frac{2M_{pl}^2}{\mathcal{L}_X}\right)^l \left(\frac{H'}{H}\right)^{l-1} \frac{H^{[l+1]}}{H}, \\
{}^l\alpha(\phi) &= \left(\frac{2M_{pl}^2}{\mathcal{L}_X}\right)^l \left(\frac{H'}{H}\right)^{l-1} \frac{(c_s^{-1})^{[l+1]}}{c_s^{-1}}
\end{aligned}
$$

Primordial perturbations

- Scalar density perturbations are responsible for structure formation,

$$\mathcal{P}_\zeta = \frac{k^3}{2\pi^2}\zeta^2,$$

Calculated at sound horizon crossing, $c_s k = aH$

- Tensor perturbations give gravitational waves,

$$\mathcal{P}_h = \frac{k^3}{2\pi^2}\left(\langle|h_{k,+}|^2\rangle + \langle|h_{k,\times}|^2\rangle\right).$$

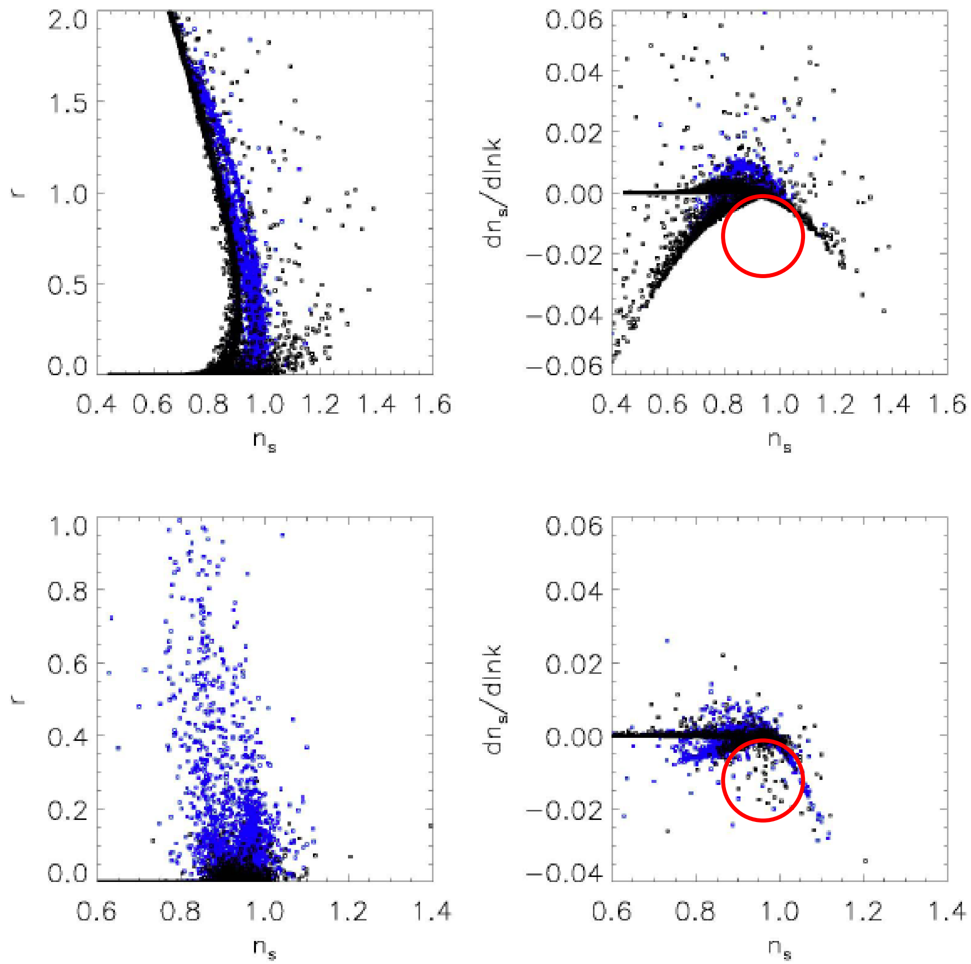
Calculated at horizon crossing, $k = aH$

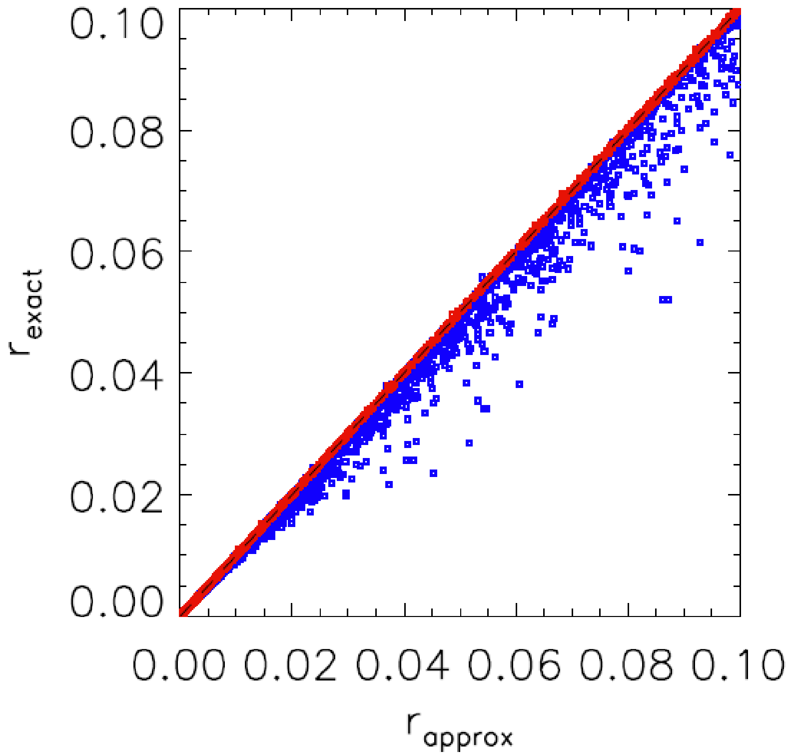
Observable predictions of inflation

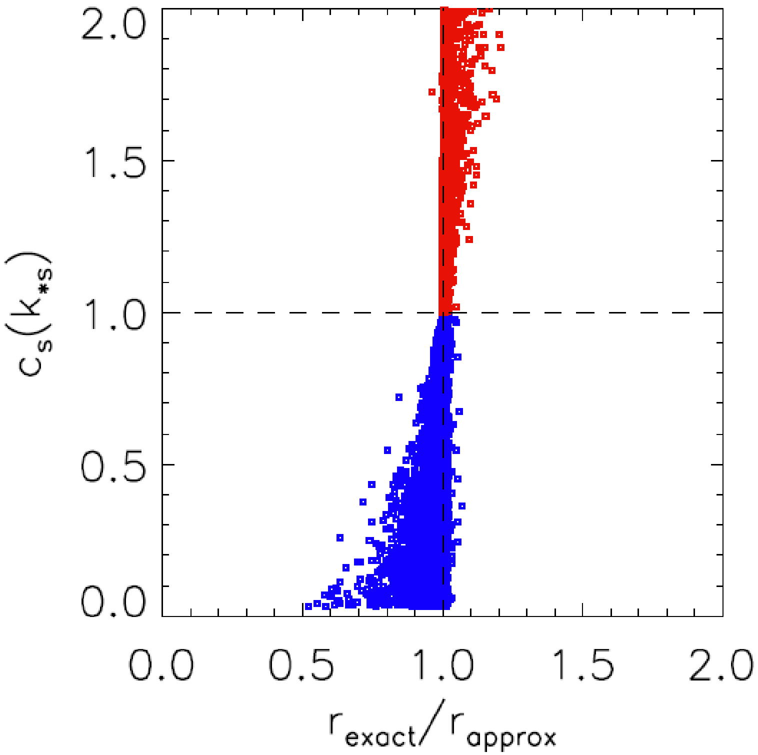
1. Monte Carlo results with end of inflation imposed

Canonical inflation

General inflation







$$
\begin{aligned}
r_{exact} &= \frac{\mathcal{P}_h(k_{*t})|_{freeze-out}}{\mathcal{P}_\zeta(k_{*s})|_{freeze-out}}, \\
r_{approx} &= 16 c_s \epsilon \left[1 + 2\kappa - b(\eta + \kappa)\right].
\end{aligned}
$$

- *L. Lorenz, J. Martin, and C. Ringeval, Phys. Rev. D 78, 083513 (2008), arXiv: 0807.3037*

2. Monte Carlo Markov Chain results with no end of inflation imposed (parameters set at horizon crossing)

- Acceleration Equation,

$$\frac{\ddot{a}}{a} = (1-\epsilon)H^2$$

- Calculate the power spectra until freeze-out, under the condition $0 \leq \epsilon < 1$ during evolution for modes in $5 \times 10^{-6}\ \mathrm{Mpc}^{-1} \leq k \leq 5\ \mathrm{Mpc}^{-1}$.

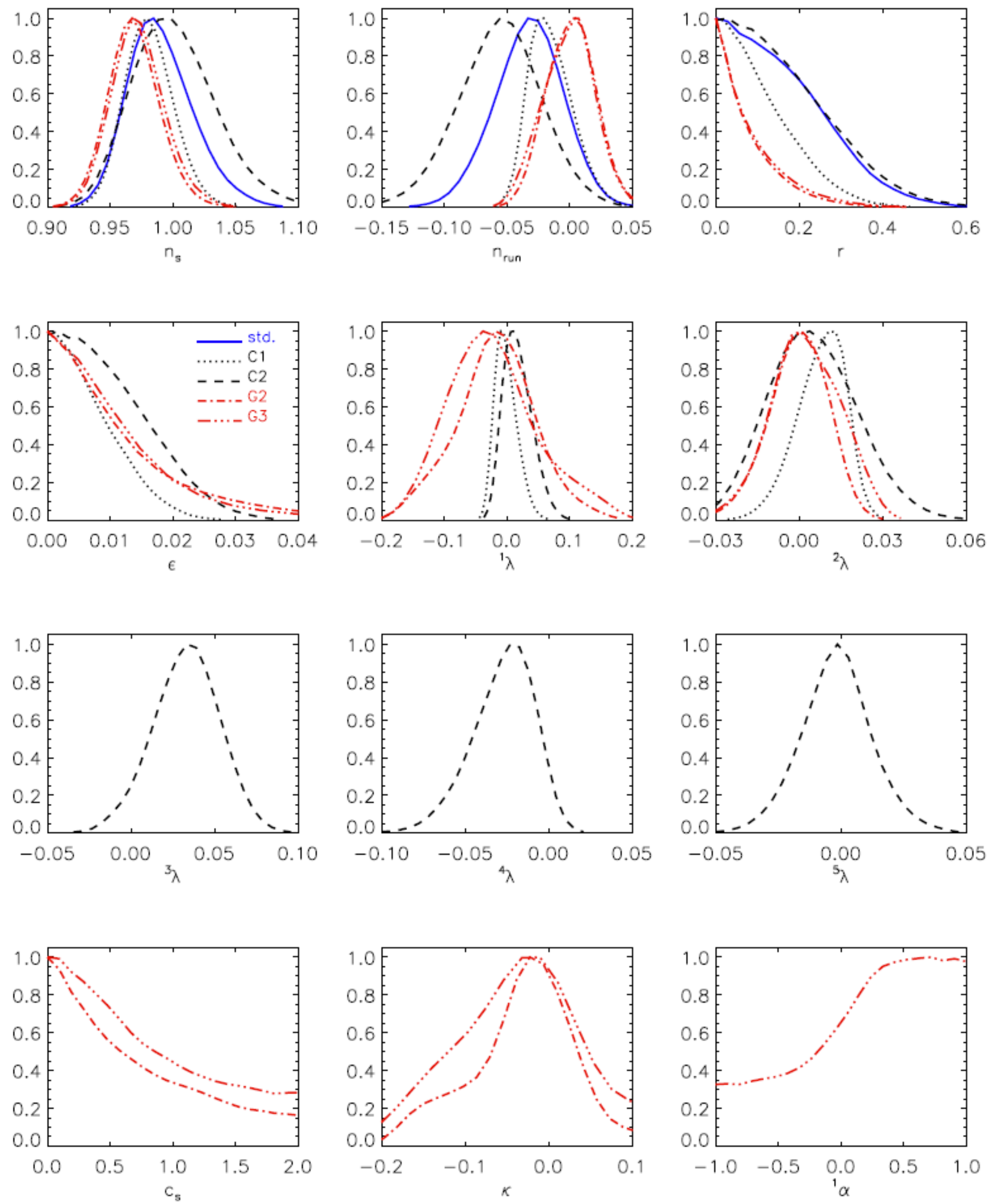
Scenario	Inflation type	c_s	ϵ	${}^l\lambda$	κ	${}^l\alpha$	$\Delta(-2\ln L)$	$\Delta(d.o.f.)$
C1	Canonical	1	[0,0.5]	[-0.1,0.1], $l_{max}=2$	0	0	1.14	0
C2	Canonical	1	[0,0.5]	[-0.5,0.5], $l_{max}=5$	0	0	1.18	3
G1	General	[0,1]	[0,0.5]	[-0.5,0.5], $l_{max}=2$	[-0.5,0.5]	0	1.16	2
G2	General	[0,2]	[0,0.5]	[-0.5,0.5], $l_{max}=2$	[-0.5,0.5]	0	0.96	2
G3	General	[0,2]	[0,0.5]	[-0.5,0.5], $l_{max}=2$	[-0.5,0.5]	[-1.0,1.0], $l_{max}=1$	1.28	3

1D posterior probability distributions

Features:

1. We are able to constrain higher order parameters in C2
2. We are able to constrain c_s and ε separately even though observations constrain only *r*, where,

$$r \approx 16 c_s \epsilon$$



Summary and Discussion

- The Hubble flow formalism can be used to reconstruct general inflation as well as canonical inflation.
- Comparison with CMB+LSS observations gives constraints on the general inflationary action.
- The next step could involve either explicitly constructing a Lagrangian for inflation, or studying different Lagrangians in light of these constraints.

Acknowledgements

Daniel Chung, Ghazal Geshnizjani, William Kinney, Istvan Laszlo, Larissa Lorenz, Jerome Martin, Brian Powell, Sarah Shandera, Henry Tye, and Alexander Vikman.

Funding:

- *Dr. Gerald A. Soffen Memorial Fund Travel Grant*
- *NASA, NSF*