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Using the Cosmic Microwave Background to Discriminate Among Inflation Models

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The upcoming satellite missions MAP and Planck will measure the spectrum of fluctuations in the Cosmic Microwave Background with unprecedented accuracy. I discuss the prospect of using these observations to distinguish among proposed models of inflationary cosmology.

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1 Introduction

There has been great interest recently in the topic of parameter reconstruction from the Cosmic Microwave Background (CMB). Most of the emphasis in the literature is on the question of determining cosmological parameters such as the density Ω_0, the Hubble constant H_0, or the value of the cosmological constant Λ. The purpose of this talk is to take a different approach and apply the machinery of CMB parameter estimation to the subject of inflationary model building.[1] I assume generic features of the universe consistent with inflation (a flat universe, vanishing Λ), but allow parameters sensitive to inflation to vary. The goal is to determine how well we will be able to distinguish between popular inflation models using upcoming CMB experiments, in particular the all-sky satellite missions MAP and Planck.

The parameters that are of interest for inflation are the ratio of tensor to scalar fluctuation amplitudes measured at the quadrupole $r \equiv C_2^{\rm tensor}/C_2^{\rm scalar}$, and the spectral index of scalar fluctuations n. Fixed parameters are the density of the universe $\Omega_0 = 1$, and the present vacuum energy $\Lambda = 0$. Other parameters are allowed to vary, and I plot the expected sensitivity of NASA's MAP satellite and the ESA's Planck Surveyor as ellipses projected onto the $r - n$ plane.

2 Inflationary Zoology

The other task is to plot the predictions of various models of inflation in the $r - n$ plane. I limit myself to models involving a single field ϕ, and divide models into three general types: *large-field*, *small-field*, and *hybrid*, with a fourth classification, *linear* models, serving as a boundary between large- and small-field. The models are distinguished by the value of the second derivative of the potential, or, equivalently, by the relationship between the values of the standard *slow-roll parameters* ϵ and η.[†] These different classes of models have readily distinguishable consequences for the CMB.

1. Large-field models are potentials typical of "chaotic" inflation scenarios, in which the scalar field is displaced from the minimum of the potential by an amount usually of order the Planck mass. Such models are characterized by $V''(\phi) > 0$, and $0 < \eta \leq \epsilon$. The generic large-field potentials I consider are polynomial potentials $V(\phi) = \Lambda^4 (\phi/\mu)^p$, and exponential potentials, $V(\phi) = \Lambda^4 \exp(\phi/\mu)$. Tensor modes are typically large in these models, with $n < 1$.

2. Small-field models are the type of potentials that arise naturally from spontaneous symmetry breaking. The field starts from near an unstable equilibrium and rolls down the potential to a stable minimum. Small field models are characterized by $V''(\phi) < 0$ and $\eta < 0 < \epsilon$. The generic small-field potentials I consider are of the form $V(\phi) = \Lambda^4 [1 - (\phi/\mu)^p]$. Tensor modes are typically small in small-field models, with $n < 1$.

3. The hybrid scenario frequently appears in models which incorporate inflation into supersymmetry. In a hybrid inflation scenario, the scalar field responsible for inflation evolves toward a minimum with nonzero vacuum energy. The end of inflation arises as a result of instability in a second field. Hybrid models are characterized by $V''(\phi) > 0$ and $0 < \epsilon < \eta$. I consider generic potentials for hybrid inflation of the form $V(\phi) = \Lambda^4 [1 + (\phi/\mu)^p]$. The distinguishing characteristic of hybrid models is a *blue* scalar spectral index, $n > 1$.

4. Linear models, $V(\phi) \propto \phi$, live on the boundary between large-field and small-field models, with $V''(\phi) = 0$ and $\eta = -\epsilon$.

[†]Here $\epsilon \propto [H'(\phi)/H(\phi)]^2$ and $\eta \propto H''(\phi)/H(\phi)$ are defined as *Hubble* slow-roll parameters, as opposed to the *potential* slow-roll form $\epsilon_V \propto (V'/V)^2$, $\eta_V \propto V''/V$.

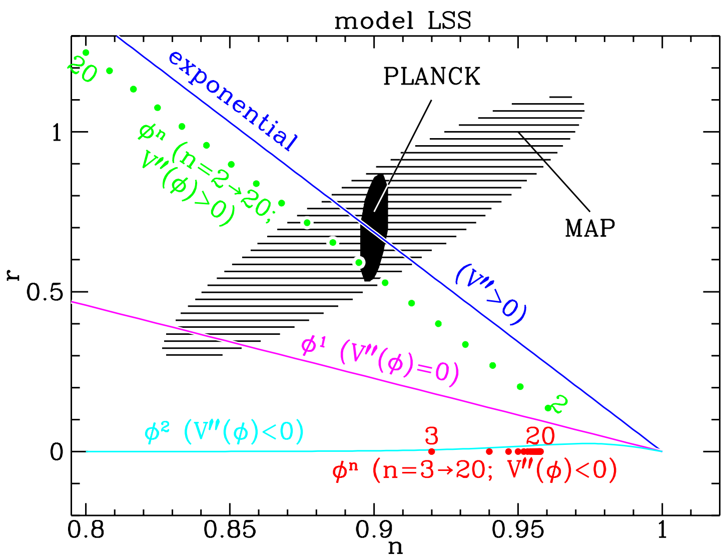

Figure 1: Models plotted in the $r-n$ plane, with 2σ error ellipses from MAP and Planck.

Figure 1 shows the models plotted in the $r - n$ plane with typical 2σ error ellipses from MAP and Planck.

3 Conclusions

It is evident from Figure 1 that MAP will allow at least rough distinction between large-field, small-field, and hybrid models. Planck, on the other hand, will allow for the beginnings of real precision work in constraining inflation models. Planck will be capable, for instance, of distinguishing the exponent p in a chaotic inflation model $V(\phi) \propto \phi^p$. David Lyth has presented thought-provoking arguments that an appreciably large r is theoretically disfavored.[2] I finish by noting that these arguments will be put to observational test within the next few years!

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[1] For details and relevant references, see S. Dodelson, W. H. Kinney, and E. W. Kolb, *Phys. Rev. D* **56**, 3207 (1997).

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[3] U. Seljak and M. Zaldariagga, *Astrophys. J.* **469**, 7 (1996).