Cosmological models predict transfer functions by which primordial density perturbations develop into CMB anisotropy and Large-Scale Structure. We use the current set of observations to reconstruct the primordial power spectrum for standard CDM, ΛCDM, open CDM, and standard CDM with a high baryon content.

1 Introduction

The combination of Cosmic Microwave Background (CMB) anisotropy measurements and Large-Scale Structure observations has caused dissatisfaction with the standard Cold Dark Matter (sCDM) cosmogony, leading some to advocate a “tilt” of the primordial power spectrum away from scale-invariant ($n = 1$) to $n = 0.8 - 0.9$. Other CDM cosmogonies have not commonly been tilted but their agreement with the data might also improve. Because the primordial power spectrum is an inherent set of degrees of freedom in all CDM cosmogonies, we adopt a set of models and find the best-fit primordial power spectrum for each. This allows us to determine if the reconstructed primordial power spectra show any common features across the set of currently preferred cosmogonies.

2 The Primordial Power Spectrum

The initial density perturbations in the universe are believed to have originated from quantum fluctuations during inflation or from active sources such as topological defects. Defect models have not yet been calculated to high precision. Inflationary models predict rough scale-invariance; the shape of the inflaton potential leads to tilting as well as variation of the degree of tilt with spatial scale. The assumption of scale-invariance is no longer acceptable because the data are now accurate enough to reveal the predicted deviations from $n = 1$. We adopt a parameterization of the primordial power spectrum as a polynomial in log-log space versus wave number $k$:

$$\log P_p(k) = \log A + n \log k + \alpha (\log k)^2 + \ldots \quad (1)$$
3 Data Analysis

Each cosmogony has transfer functions, $T(k)$ and $C_{lk}$. CMB anisotropies are given by

$$C_l = \frac{1}{8\pi} \sum_k d \log k C_{lk} P_p(k),$$

(2)

where $C_{lk}$ is the radiation transfer function after Bessel transformation into $\ell$-space. The matter power spectrum is

$$P(k) = \frac{2\pi^2 c^3}{H_0^3} T^2(k) P_p(k).$$

(3)

We can predict the value of $\sigma_8$ using

$$\sigma^2_R = \frac{2}{\pi^2} \int d \log k W^2(kR) k^3 P(k)$$

(4)

where $W(kR)$ is a top-hat window function on the $R = 8h^{-1}\text{Mpc}$ scale.

We use the CMB anisotropy observations catalogued in Scott, Silk and White, plus recent additions from Saskatoon, CAT and the COBE 4-year data. Peacock and Dodds provide a careful compilation of the matter power spectrum, to which we add measurements of the power spectrum from peculiar velocities and $\sigma_8$ from clusters. For a given $P_p(k)$, we compare predictions with observations using the $\chi^2$ statistic. We vary the coefficients of $P_p(k)$ given in Equation 4 to find the best fit for each cosmogony.

| Model          | $h$ | $\Omega_{\text{baryon}}$ | $\Omega_{\text{matter}}$ | $\Omega_\Lambda$ |
|----------------|-----|---------------------------|---------------------------|------------------|
| standard CDM   | 0.50| 0.05                      | 1.0                       | 0.0              |
| high-B sCDM    | 0.50| 0.10                      | 1.0                       | 0.0              |
| $\Lambda$ CDM  | 0.65| 0.04                      | 0.4                       | 0.6              |
| Open CDM       | 0.65| 0.04                      | 0.4                       | 0.0              |

4 Results

Our results are preliminary, but we have a qualitative understanding of the reconstructed primordial power spectra for each cosmogony. If we restrict $P_p(k)$ to scale-invariant ($n = 1$, $\alpha = 0$), the $\Lambda$CDM and OCDM models are a good fit to the data (meaning $\chi^2$ per degree of freedom is about 1). The
sCDM variants are poor fits, although high-B sCDM is better. Assuming only scale-free $P_p(k) (\alpha = 0)$, the sCDM models prefer $n = 0.8$. The $\Lambda$CDM and OCDM models choose a slight tilt ($n = 1.1$) but their agreement with the data only improves marginally, with $\Lambda$CDM fitting the CMB anisotropy data better than OCDM. Allowing the scalar index $n$ to “run” yields interesting results; the $\Lambda$CDM and OCDM models prefer $\alpha=0$, so they remain good fits. The two sCDM models become good fits, with $n = 1.3$ on COBE scales and running by $\alpha = -0.1$. There is nothing to be gained by fitting additional terms of $P_p(k)$, as all four cosmogonies already fit the data well.

5 Conclusions

Assumptions about the primordial power spectrum make a tremendous difference in testing theories of structure formation. Allowing the power-law index to run makes standard CDM a good fit to the data, despite the apparent superiority of low $\Omega_{\text{matter}}$ models when restricted to a scale-invariant $P_p(k)$. Combining Large-Scale Structure observations with CMB anisotropy data gives us a long lever arm in k-space with which to reconstruct the primordial power spectrum. With the next generation of observations, we hope that our technique will prove powerful enough to either discredit inflation or reconstruct the inflaton potential.

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