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Evolution of the CMB Power Spectrum Across WMAP Data Releases: A Nonparametric Analysis

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Using a nonparametric function estimation methodology, we present a comparative analysis of the WMAP 1-, 3-, 5-, and 7-year data releases for the CMB angular power spectrum with respect to the following key questions: (a) How well is the power spectrum determined by the data alone? (b) How well is the ΛCDM model supported by a model-independent, data-driven analysis? (c) What are the realistic uncertainties on peak/dip locations and heights? Our results show that the height of the power spectrum is well determined by data alone for multipole l approximately less than 546 (1-year), 667 (3-year), 804 (5-year), and 842 (7-year data). We show that parametric fits based on the ΛCDM model are remarkably close to our nonparametric fits in l-regions where data are sufficiently precise. In contrast, the power spectrum for an HΛCDM model gets progressively pushed away from our nonparametric fit as data quality improves with successive data realizations, suggesting incompatibility of this particular cosmological model with respect to the WMAP data sets. We present uncertainties on peak/dip locations and heights at the 95% (2σ) level of confidence, and show how these uncertainties translate into hyperbolic "bands" on the acoustic scale (l_A) and peak shift (ϕ_m) parameters. Based on the confidence set for the 7-year data, we argue that the low-l up-turn in the CMB power spectrum cannot be ruled out at any confidence level in excess of about 10% ($\approx 0.12 \sigma$). Additional outcomes of this work are a numerical formulation for minimization of a noise-weighted risk function subject to monotonicity constraints, a prescription for obtaining nonparametric fits that are closer to cosmological expectations on smoothness, and a method for sampling cosmologically meaningful power spectrum variations from the confidence set of a nonparametric fit.

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