Mapping, Measuring, and Modelling the Universe
ASP Conference Series, Vol. 94, 1996
Peter Coles, Vicent J. Martinez, and Maria-Jesus Pons-Borderia (eds.)

Is Tenerife Sampling an Active Region of the CBR Temperature Fluctuation Sky?.

F. Atrio–Barandela

Física Teórica. Facultad de Ciencias. 37008 Salamanca, Spain

L. Cayón

Lawrence Berkeley Laboratory and Center for Particle Astrophysics,
University of California, Berkeley, CA 94720

Abstract. We analyze whether the large variance of the temperature field measured by the Tenerife experiment can be obtained sampling an active region of a cosmic microwave sky characterized by a matter power spectrum with slope $n = 1$. We employ the technique of constrained realizations of gaussian random fields to generate sky maps, smoothed to COBE/DMR scales, containing a hot spot at a prespecified location. We show that when Tenerife is normalized to $Q_{rms-PS} = 20\mu$K, the high variance can be explained at the 68% confidence level as originating from 2.5σ deviation or larger from a scale invariant power spectrum.

1. Introduction

Temperature fluctuations in the microwave background provide a unique test of models of galaxy formation. Comparison of theoretical predictions and observations requires a careful analysis of the statistical uncertainties associated with each measurement, such as systematic errors, foreground contamination and cosmic and sampling variances, before concluding that a model is ruled out by observations. The slope of matter density perturbations, and also the amplitude and location of the Doppler peak are not yet well determined. For example, while the analysis of the COBE/DMR indicates that n is close to unity (Gorski et. al. 1994), the favorite value of inflation, the Tenerife experiment has measured a r.m.s. temperature anisotropy $\sigma_{TEN} = 42 \pm 9\mu$K that, if normalized to COBE/DMR first year data indicates $n = 1.7$ (Hancock et al. 1994).

In this article, we will assume that the temperature anisotropies on the sky originated from matter density perturbations with $n = 1$. We will study whether the presence of a spot on the underlying temperature field sampled by Tenerife could significantly alter the variance measured from the scan.

2. Analysis of Simulated Tenerife Scans

Tenerife and COBE/DMR window function overlap over a wide range in l space, structure seen at Tenerife scales should also be present on the COBE/DMR

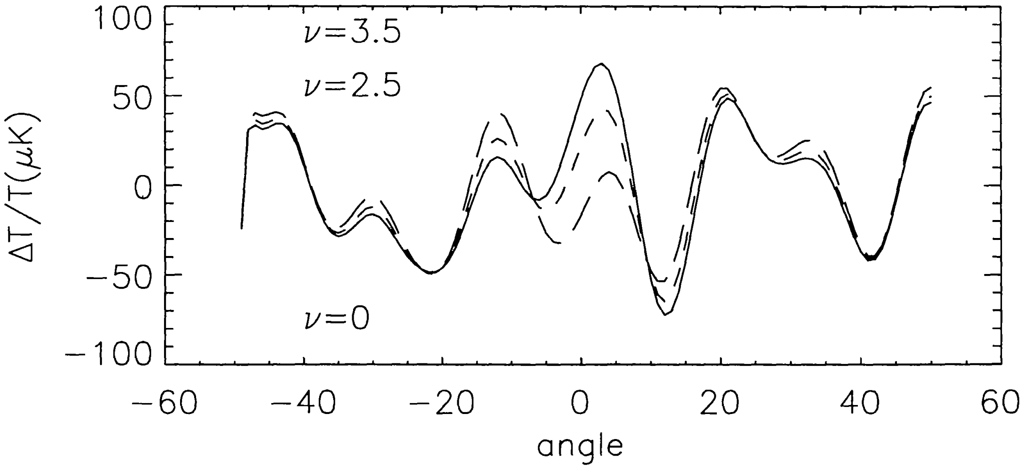

Figure 1. Tenerife scans generated from an unconstrained simulation (long dashed). The constrained density fields correspond to spots of amplitude $\nu = 3.5$ (solid line) and $\nu = 2.5$ (dashed line) on the CBR map, located at the center of the scan. Constrained and unconstrained scans have zero mean, and are derived from full sky maps with normalization $Q_{rms-PS} = 20\mu$K. The temperature scale is in thermodynamic units.

scales. Even though the COBE/DMR second year data is dominated by noise, there have been attempts to identify intrinsic spots (Bunn et al. 1994, Cayón & Smoot 1995). The largest Tenerife spot is also seen in the COBE/DMR maps of the two highest frequency channels (Lineweaver et al. 1994). But because it is not observed at the lowest frequency channel, the exact amplitude of the spot is unreliable. We will therefore vary the spot height in our study. We intend to quantify how large the variance measured by Tenerife could be if this experiment was sampling an active region of a CBR sky characterized by a $n = 1$ matter power spectrum. We compute the probability of measuring a r.m.s. temperature anisotropy σ_T when observing a scan T (as if observed by the Tenerife experiment) that crosses a spot of height $\nu\sigma_{CBR}$: $p[\sigma_T|\nu]$. For this purpose we generate full sky maps by drawing the amplitude of the spherical harmonic expansion given by (Bond & Efstathiou, 1984):

$$< |a_{lm}|^2 >= 4\pi/5Q^2_{rms-PS}\frac{\Gamma(l+(n-1)/2)\Gamma((9-n)/2)}{\Gamma(l+(5-n)/2)\Gamma((n+3)/2)}, \qquad (1)$$

with $n = 1$. Our calculations were normalized to $Q_{rms-PS} = 20\mu$K (Gorski et al. 1994). Since the correlation function is linear on Q^2_{rms-PS} all our results can be easily rescaled.

The simulated CBR sky map was generated using the first 70 multipoles and filtered with a gaussian window of beamwidth $\beta = 7^o$, similar to COBE/DMR. On this map we impose a single constraint using the technique of constrained realizations (Van de Weygaert & Bertschinger 1995). We add a hot spot of height $\nu\sigma_{CBR}$ at location x_1, where σ_{CBR} is the r.m.s. temperature fluctuation. Because of the large beamwidth, the spot has an angular size of, roughly, 20^o which corresponds to the size of the spot seen by Tenerife. We superposed spots of eight different heights: $\nu = 0, 0.5, ..., 3.5$. Further, we recovered the multipoles from the constrained map up to $l = 20$ since, due to filtering, higher order multipoles are not affected by the constraining process. We added the other 50 multipoles to complete the set of 70 that will be needed to construct Tenerife scans. We sample the spot using the proper window function and adding the necessary noise level to reproduce the Tenerife experimental setup. The spot was placed at the center of the scan. Finally, we subtract any baseline present to guarantee that the mean temperature is zero. As an example of the procedure, Fig.1 shows a Tenerife scan sampling an unconstrained (long dashed) and two constrained fields. Notice that the temperature outside the spot is smaller in the constrained maps due to baseline subtraction.

In total, we have generated 1200 simulations per spot level ν in order to compute the probability distribution $p[\sigma_T|\nu]$. In Table 1 we present the statistical parameters describing the distribution for the different levels: mean, with the 68% confidence interval, and mode. As expected, higher amplitude spots give rise to larger variances. In column 4 we give the probability of measuring a scan with a variance equal or larger than 42μK.

Table 1. Statistical parameters for the distribution of r.m.s. temperature fluctuations of the 1200 scans for each spot level. Column 4 gives the probability of obtaining the r.m.s. temperature anisotropy equal or larger than 42μK for the Tenerife experiment.

level	mean/μK ($\pm$68% c.l.)	mode/μK	P($\sigma_T \geq 42\mu$K)
3.5	40.4(+7.1, −8.5)	38.0	39%
3	38.5(+6.7, −8.0)	36.7	28%
2.5	36.8(+6.6, −7.4)	34.8	21%
2	35.4(+6.3, −7.2)	32.4	15%
1.5	34.2(+6.1, −6.9)	31.1	10.5%
1	33.3(+5.9, −6.6)	32.3	8.8%
0.5	32.8(+5.8, −6.5)	31.1	6.7%
0	32.6(+5.8, −6.5)	29.2	5.9%

We check our method by integrating over all possible values of ν to verify that we recover the unconstrained result:

$$\pi[\sigma_T] = \int p[\sigma_T|\nu]\pi[\nu]\mathrm{d}\nu, \qquad (2)$$

where $\pi[\nu] \propto \exp(\nu^2/2)$ is the probability of having a spot of height ν in the CBR map smoothed on COBE/DMR scales and $\pi[\sigma_T]$ is the probability of measuring the observed standard deviation σ_T. In Fig.2 we show the distribution (solid line) obtained after marginalizing the height of the spot (eq.[4]) and for comparison, we also plot the distribution obtained from unconstrained realizations (dashed line). The overall shape is rather similar even though the mean of the distribution is shifted but well within the errors due to the small number of simulations.

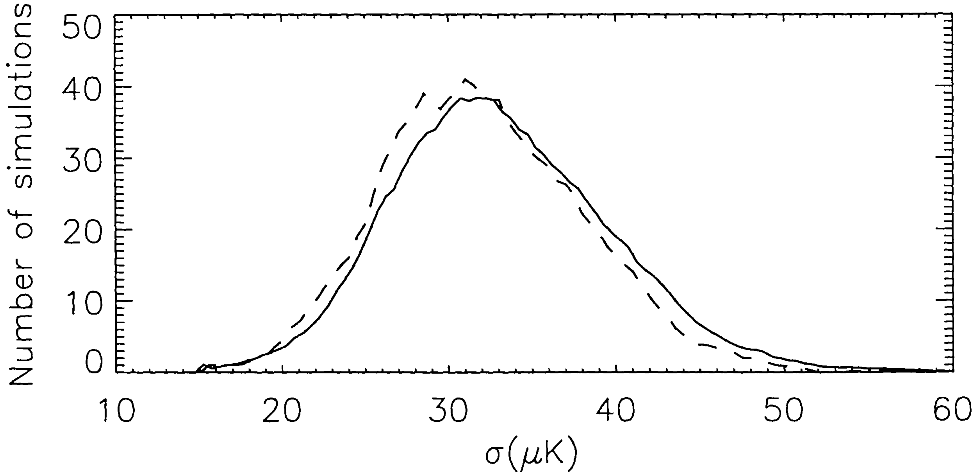

Figure 2. Probability distribution of the weighted average (eq.[4]) of all constrained realizations (solid line) and of the unconstrained realizations (dashed line).

To summarize, the presence of cosmological spots on COBE/DMR sky maps can be taken into account when interpreting the results from Tenerife. As an example, assuming $n = 1$ and $Q_{rms-PS} = 20\mu$K if in a COBE/DMR map filtered with a Wiener filter (Bunn *et.al.*1994) the level of the spot crossed by Tenerife was $\nu = 1.5$, one could use Table 1 to compute the likelihood of the measured variance $\sigma_{TEN} = 42\mu$K. In this case, the probability of measuring this or a larger variance is 11.5%, well outside the 68% confidence level. On the other hand, for $\nu = 3.5$ the σ_{TEN} is very close to the mean value. For a different quadrupole, the mean, mode and confidence levels in Table 1 should be rescaled by the factor Q_{new}/Q_{old}. High quadrupole values will allow for σ_{TEN} to be within the 68% confidence interval with lower spot amplitudes.

3. Conclusions.

CBR experiments measure a single realization of the temperature fluctuation field. In this article we were concerned that large excursions in the temperature field observed by low angular resolution experiments could leave an imprint on higher resolution observations of the same region. We showed that the variance estimated from a Tenerife type experiment could be significantly altered.

Theoretical models of Large Scale Structure are usually compared with observations of CBR temperature anisotropies using Monte Carlo simulations to compute the set of parameters that best fit the observational data, while taking into account cosmic and sampling variances, as well as experimental noise. Additional information concerning the presence of a hot (or cold) spot in the sampled field has been accounted for by using constrained realizations of Gaussian Random Fields techniques. The simulations were performed assuming a scale invariant matter density power spectrum with amplitude $Q_{rms-PS} = 20\mu$K. The presence of a spot on COBE/DMR scales of height equal or larger than 2.5σ can account for the measured value $42\mu K$ at the 68% confidence level. Therefore this effect solely can explain the Tenerife result without requiring the spectral index of the matter density power spectrum to be larger than unity.

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