

EP20BTECH11015 - Assignment 4 Question 3

Application of the Kolmogorov-Smirnov test to CMB data: Is the universe really weakly random?

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In this work, 1-sample KS test was applied to WMAP's Cosmic Microwave Background (CMB) maps, and questions whether the CMB is *weakly random* as claimed by previous works also using KS test.

The data samples used in this paper are correlated so fundamentally, the KS test cannot be (immediately) applied. So A whitening transformation replacing the hypothesis $\mathbf{d} \leftarrow \mathbf{N}(\mathbf{0}, \mathbf{C})$ with the equivalent $\mathbf{r} = \mathbf{C}^{-1/2} \mathbf{d} \leftarrow \mathbf{N}(\mathbf{0}, \mathbf{1})$, is used. This results in an i.i.d for the samples. (\mathbf{d} are the original samples, with covariance matrix \mathbf{C} , and \mathbf{r} are the *whitened* samples (uncorrelated with unit variance)).

From the WMAP 7-year W-band map, 10,000 disks are picked with a radius of 1.5 degrees. If the model claimed by the author was correct, the probability $P(x < K)$ should follow the distribution $\mathbf{N}(\mathbf{0}, \mathbf{1})$ after whitening. Where K is the maximum distance between the theoretical CDF and the CDF of data. Also the sample size is not infinity so an approximation is used to apply the 1 sample KS test.

The resulting probabilities from applying the equation $P(x < K) = G(F_{KS}(\sqrt{N_{\text{obs}}}K))$ for the hypothesis $\mathbf{r} \leftarrow \mathbf{N}(\mathbf{0}, \mathbf{1})$ were binned into a histogram which followed a uniform distribution. This suggested that the CMB map was consistent with Λ CDM + WMAP noise by the K-S test, and the universe is not *weakly random*.

This result disproves a previous work claiming the detection of an unknown component making up 80% of the CMB, as it did not account for the CMB correlations. Without the whitening transformation used, the same data failed the KS test in the previous work which led to incorrect inferences.

Both works apply the KS test in ways which might be considered misuse by the Penn State University as the present one uses a transformation over a correlated dataset and using an approximation to accommodate finite no.of samples in 1D KS test, while the previous work arrives at a wrong conclusion with the results of the KS test.

References:

This work: <https://www.aanda.org/articles/aa/pdf/2012/02/aa17344-11.pdf>

The previous work which was disproved:

https://www.aanda.org/articles/aa/full_html/2011/01/aa16012-10/aa16012-10.html