Wilkinson Microwave Anisotropy Probe 7-yr constraints on f_{nl} with a fast wavelet estimator

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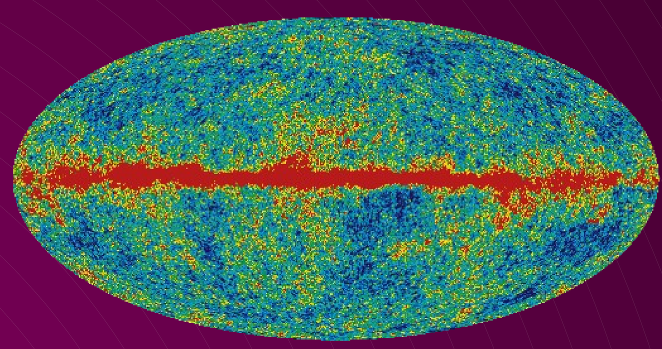
The cosmic microwave background (CMB) is one of the pilars that provide support to the Big Bang theory. The fluctuations of the CMB naturally arise in an inflationary scenario. The understanding of this very early stage of the Universe is a challenging issue for the scientific community due to the implications on large scale structure formation and fundamental particle physics at high energies.



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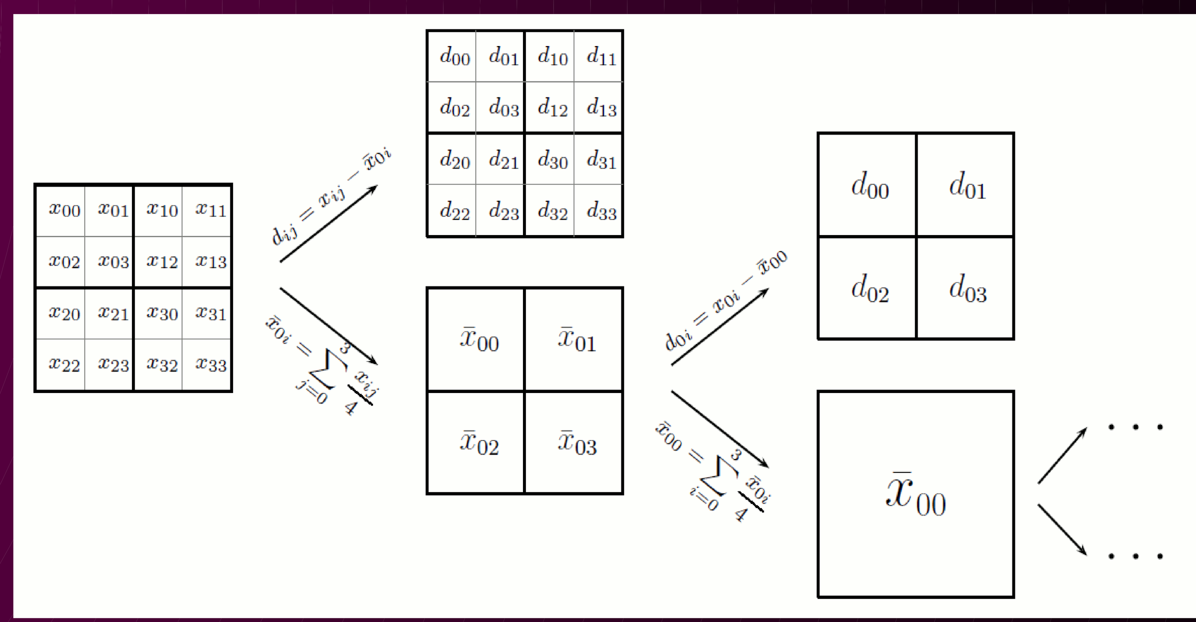
A large number of inflationary models have been proposed in the literature but the task of testing such scenarios is not trivial, and there is the need of new experiments and powerful statistical tools to discriminate among them. In this sense, the statistical properties of the CMB temperature anisotropies are a source of information about the processes that have generated the primordial fluctuations.

1.Quadratic parametrization

In particular, the standard, slow roll, single field inflationary model predicts a nearly Gaussian distribution of the CMB temperature anisotropies, while alternative models may introduce a certain level of non-Gaussianity in the CMB. A convenient parametrization valid for a large set of non-standard inflationary models which includes the quadratic corrections of the primordial curvature perturbation is (Salopek & Bond 1990; Gangui et al. 1994; Verde et al. 2000; Komatsu & Spergel 2001):

$$\phi(r)=\phi_L(r)+f_{nl}[\phi_L^2-\langle\phi_L^2\rangle]$$

2.HEALPix wavelet



HEALPix wavelet diagram

In this work (Casaponsa et al. 2010) we decompose the maps of anisotropies with the so-called HEALPix wavelet (HW). The HW is a discrete, orthogonal wavelet adapted to the hierarchical pixelization (such as HEALPix, Górski et al. 2005). We compute the third order moments of the wavelet coefficients to perform a Gaussianity analysis and the estimation of f_{nl} . The interest of using this tool is that is very simple and 10^3 **times faster than the KSW estimator (bispectrum)** (Komatsu et al. 2005) and 10^2 **times faster than the SMHW** (Curto et al. 2010).

3.Gaussianity analysis

We have performed a Gaussianity test based on the statistic χ^2.
We compute the distribution of this statistic for 1000 Gaussian simulations and compare it with the value obtained with the data with a cumulative probability of 0.96

$$\chi^2=\sum_{i,j}^{n_{stat}}(v_i-\langle v_i\rangle)C_{ij}^{-1}(v_j-\langle v_j\rangle)$$

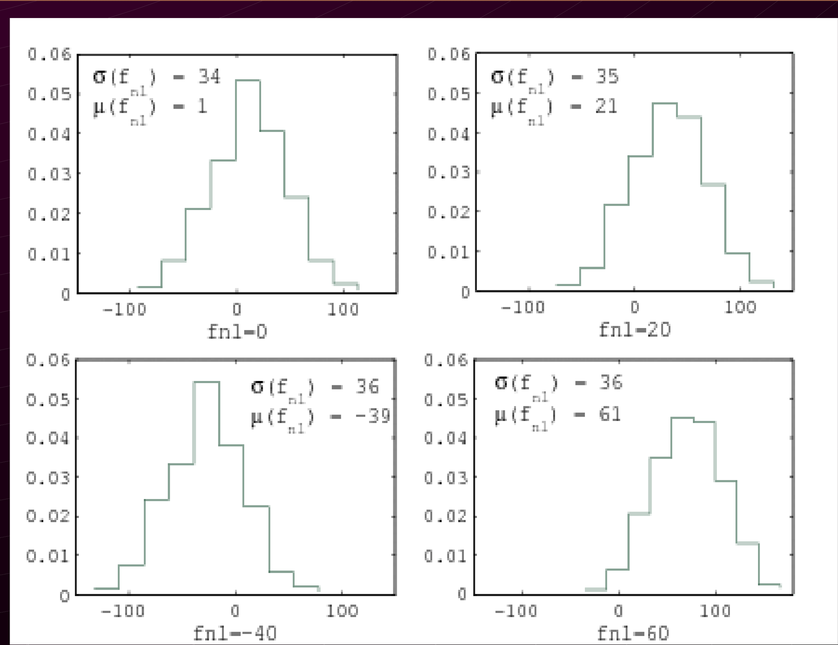
v_i are the third order moments for the data

$\langle v_i\rangle$ and C_{ij} are the expected value and the covariance matrix of the third order moments computed with Gaussian simulations

4.f_{nl} constraints

We have estimated the non-linear coupling parameter fnl using 1000 non-Gaussian simulations generated by Elsner & Wandelt 2009. After obtaining the cubic statistics of the wavelet coefficients we minimize χ^2 to estimate the best-fit value of fnl for the data, which is found to be **fnl=6**.

$$\chi^2=\sum_{i,j}^{n_{stat}}(v_i-\langle v_i\rangle_{fnl})C_{ij}^{-1}(f_{nl})(v_j-\langle v_j\rangle_{fnl})$$



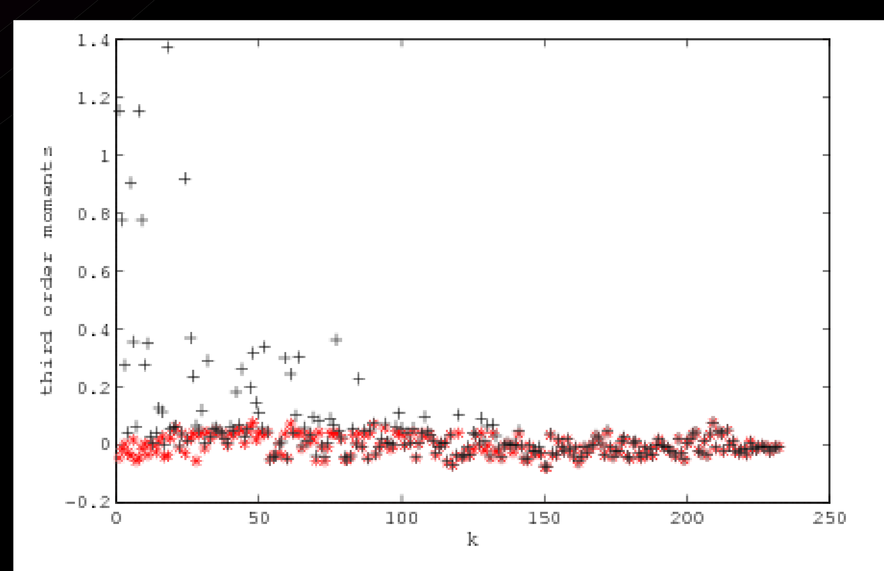
Histograms of the best fit value of fnl for 1000 simulations with different values of fnl.

The constraints obtained are **$-69 < f_{nl} < 65$** after correcting for the contribution of residual point sources (explained in point 5.)

Finally we have analysed the data considering two independent hemispheres associated to the dipolar modulation proposed by Hoftuft et al. 2009. We find for the **northern hemisphere $-73 < f_{nl} < 119$** and for the **southern $-137 < f_{nl} < 62$.** The difference between f_{nl} estimated in both hemispheres for the data is $\Delta f_{nl}=67$. We have checked that with Gaussian simulations we obtain a $\sigma(\Delta f_{nl})=71$. Then we cannot conclude any significant asymmetry.

5.Point sources correction

The undetected point sources may introduce a bias in the estimation of fnl. In order to correct this bias we have produced point sources simulations following the procedure of Curto et al. 2009. The point sources simulated follow the density distribution given by de Zotti et al. 2005 in a range of intensities between 1mJy and 1 Jy. We have found a contribution of **$\Delta f_{nl}=7\pm 6$**.



Mean values of the third order moments from 1000 simulations. Diamonds represent CMB+noise simulations and crosses CMB+noise+point sources.

6.Conclusions

The HEALPix wavelet is 100 times faster than the spherical Mexican hat wavelet and 1000 faster than the KSW bispectrum estimator.

We do not find a significant deviation of the Gaussian distribution when we compare the data with Gaussian simulations.

The constraints on f_{nl} after correcting for the constribution of residual point sources is **$-69 < f_{nl} < 65$.**

With the HW it is possible to do localized tests. We do a hemispherical analysis and we do not find any significant asymmetry between the two hemispheres proposed by Hoftuft et al 2009.

References

Casaponsa B., Barreiro R.B., Curto A.,Martínez-González E., Vielva P., arXiv:1009.0632

Curto A., Martínez-González E., Barreiro R. B., 2010, arXiv:1007.2181

Curto A., Martínez-González E., Barreiro R. B., 2009b, ApJ

de Zotti G., Ricci R., Mesa D., Silva L., Mazzotta P., Toffolatti, L., Gonz´alez-Nuevo J., 2005, A&A, 431, 893

Elsner F., Wandelt B. D., 2009, ApJS, 184, 264

Gangui A., Lucchin F., Matarrese S., Mollerach S., 1994, ApJ, 430, 447

Górski K. M., Hivon E., Banday A. J., Wandelt B. D., Hansen F. K., Reinecke M., Bartelmann M., 2005, ApJ, 622, 79

Hoftuft J., Eriksen H. K., Banday A. J., Górski K. M., Hansen F. K., Lilje P. B., 2009, ApJ, 699, 985

Komatsu E., Smith K. M., Dunkley J., Bennett C. L., Gold B. e. a., 2010, arXiv:1001.4538

Komatsu E., Spergel D., 2001, Phys.Rev.D, 63, 063002 Salopek D. S., Bond J. R., 1990, Phys.Rev.D, 42, 3936

Verde L.,Wang L., Heavens A. F., Kamionkowski M., 2000, MNRAS, 313, 141