Destriping of Polarized and Unpolarized CMB Data

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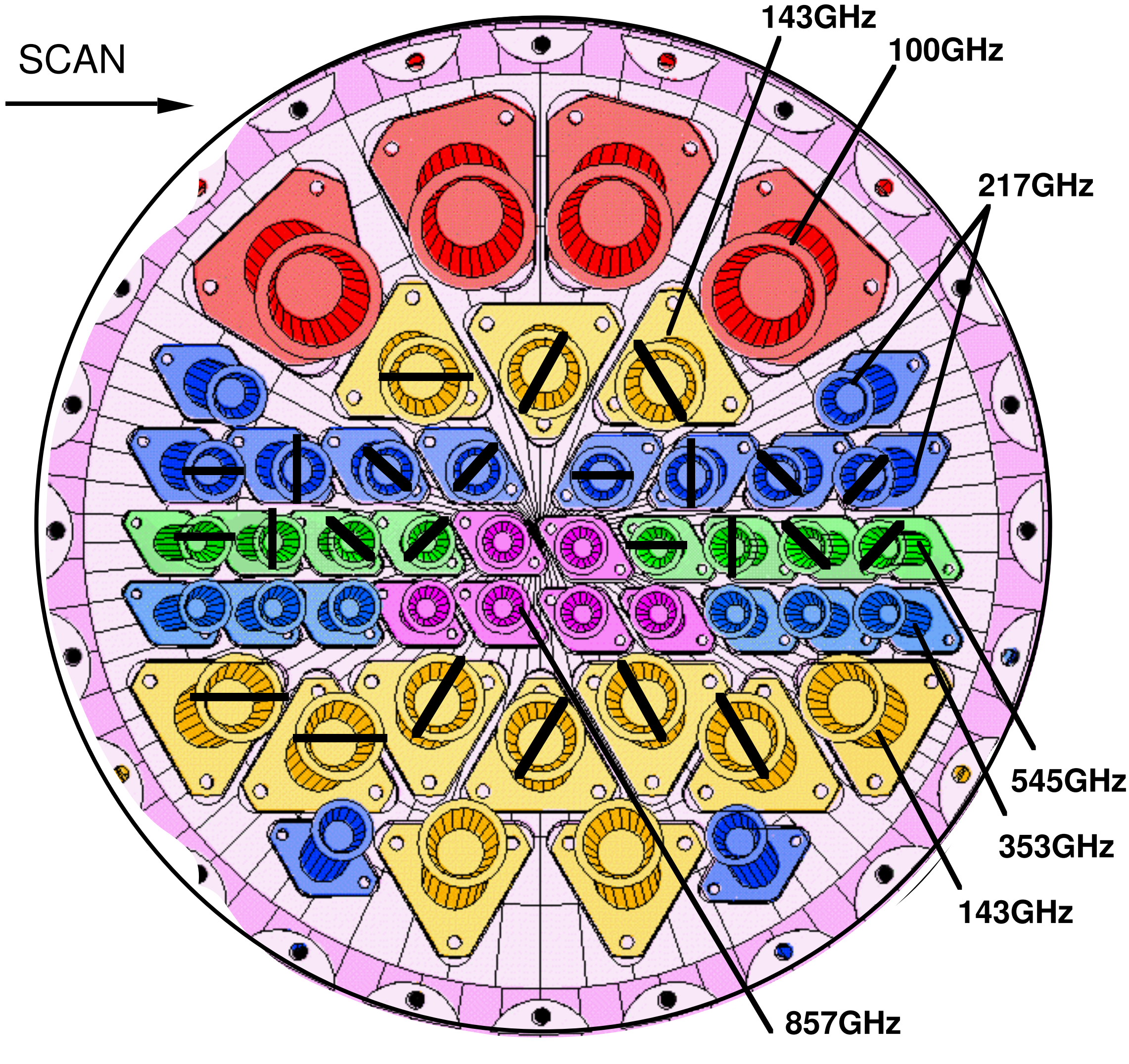
The HFI in the focal plane of Planck



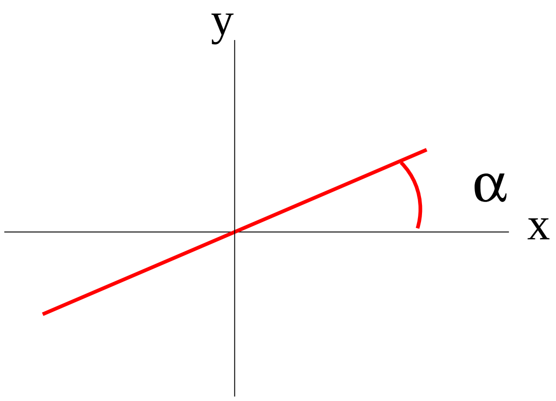
What does a polarimeter measure ?

The power measured by a polarimeter is of the form:

$$m_p = \frac{1}{2}\left(I + Q\cos 2\alpha + U\sin 2\alpha\right)$$

where I, Q and U are the Stokes parameters of the incoming wave and α is the angle between the polarimeter and an arbitrary axis of reference.

reference



The measurement depends on the reference system.

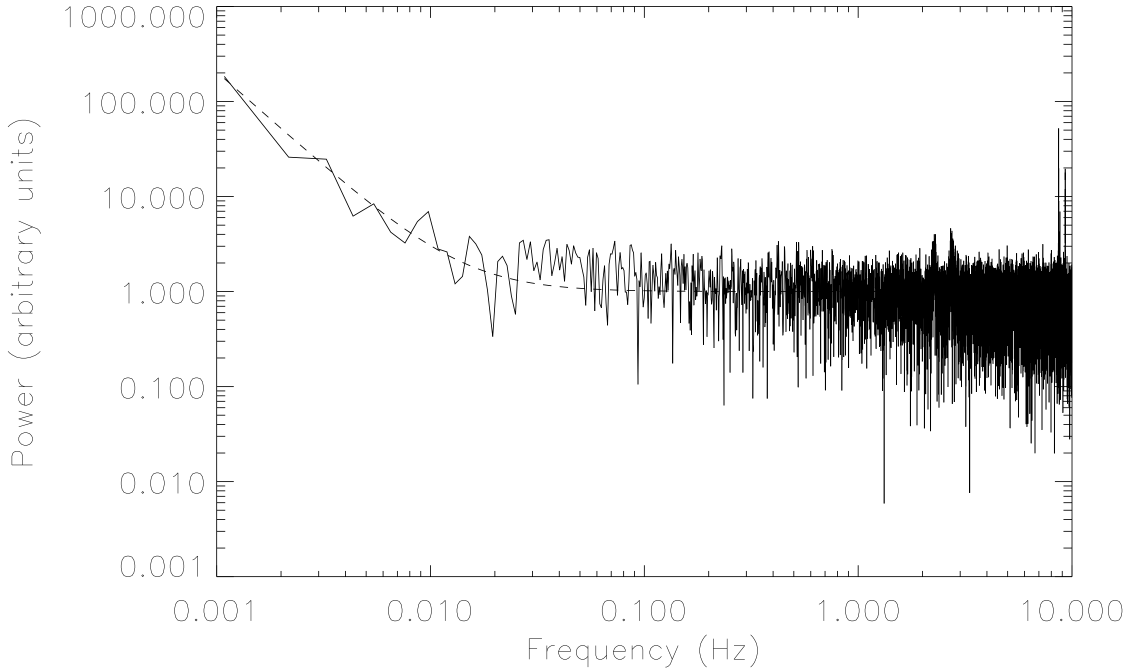
3 Stokes parameters: at least 3 polarimeters.

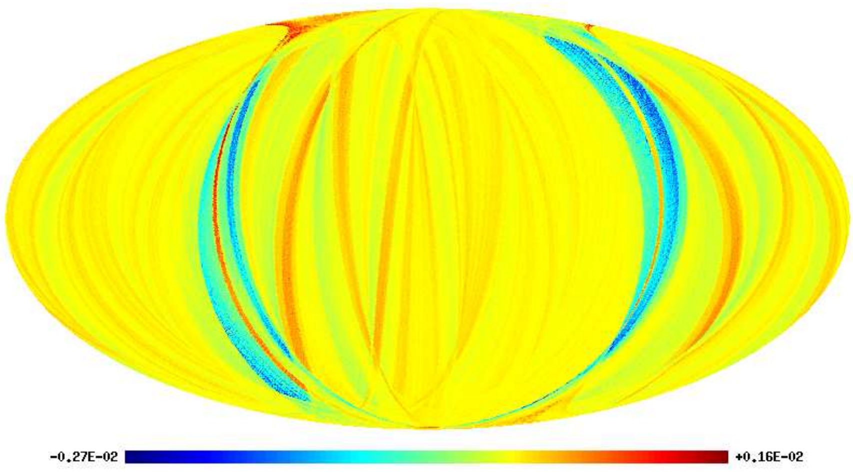
The low-frequency drifts

Thermal instabilities : $1/f^2$

and $1/f$ noise from the electronics.

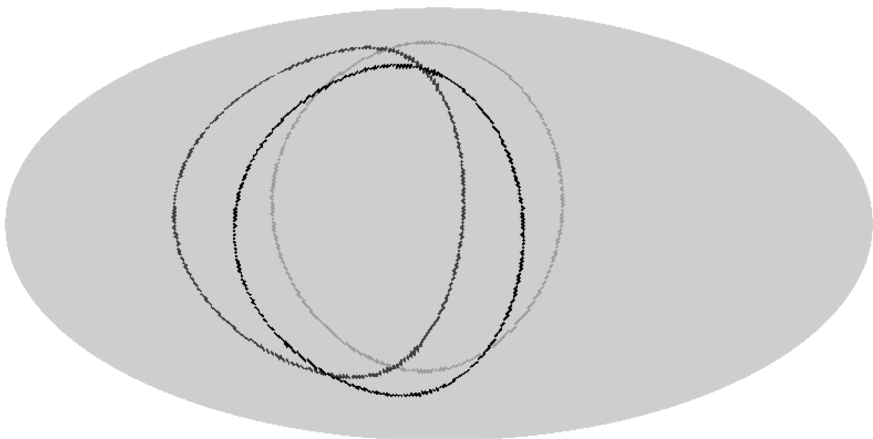
Measured spectrum:

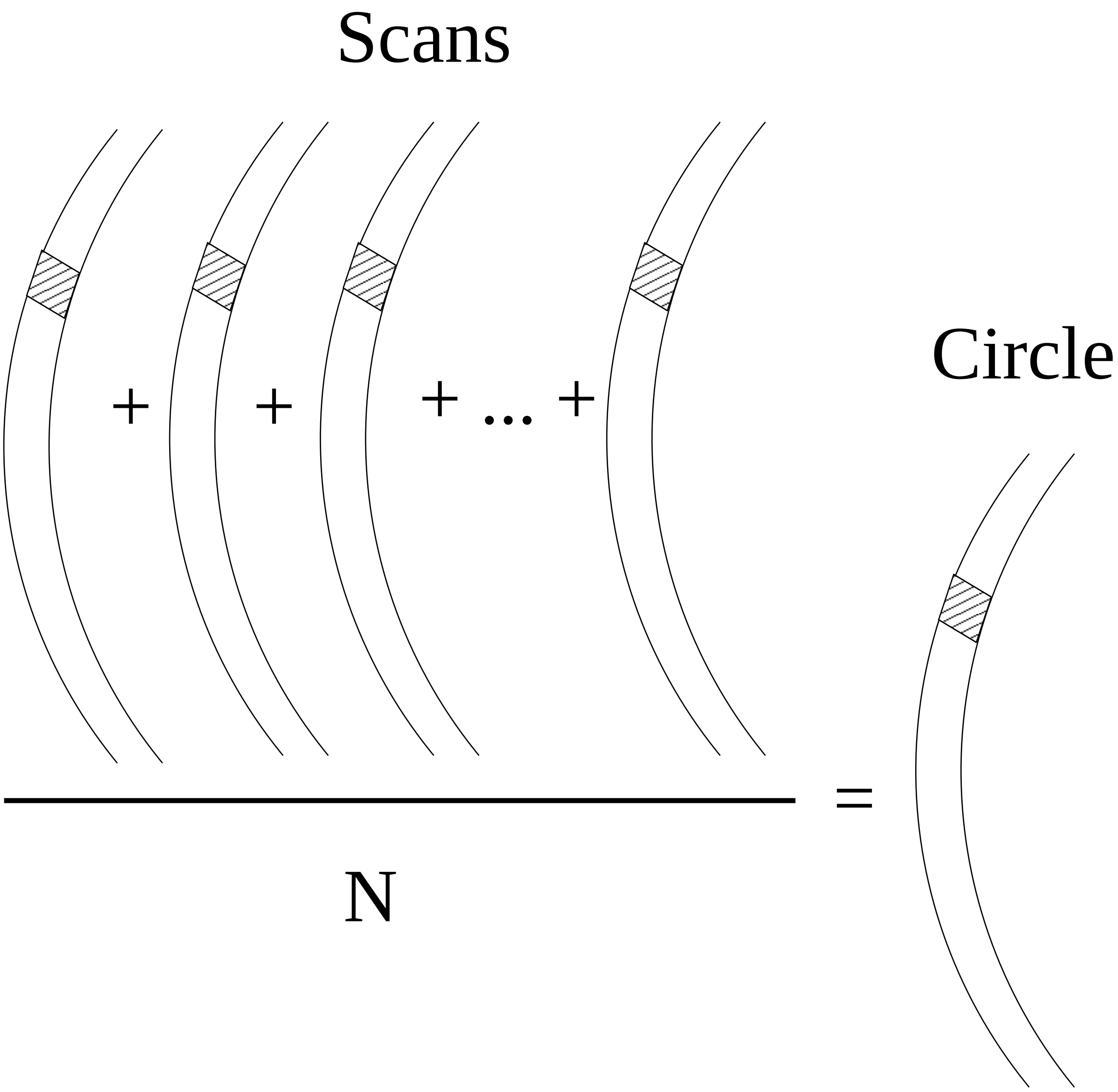




The noise is greater than $\Delta T/T$ and polarization: need to be removed.
We use for that the two kinds of redundancies provided by the scanning strategy:

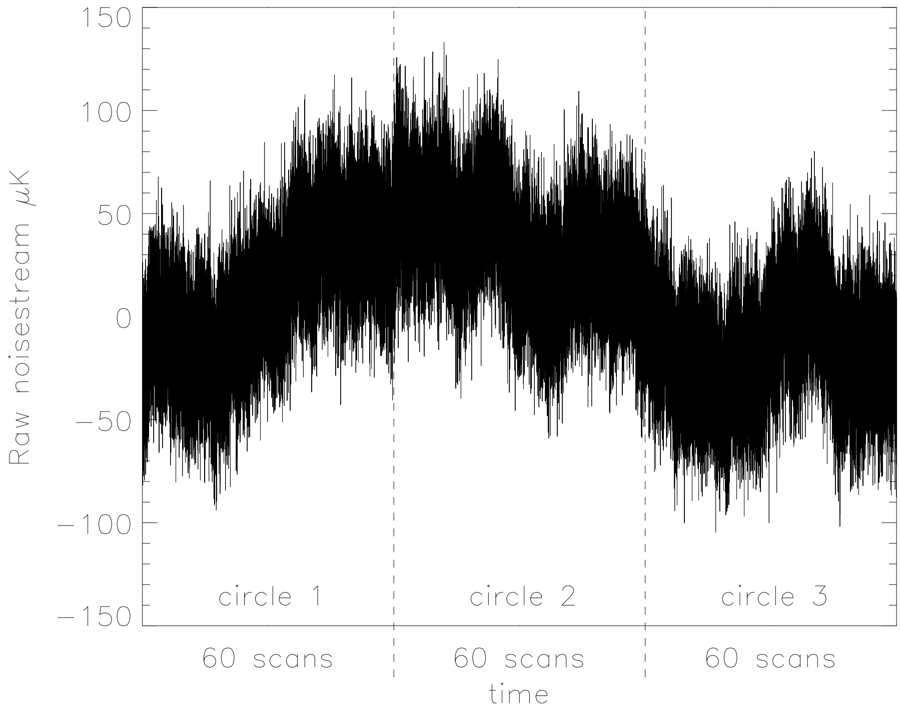
1. each circle is scanned ~ 60 times
2. the circles intersect



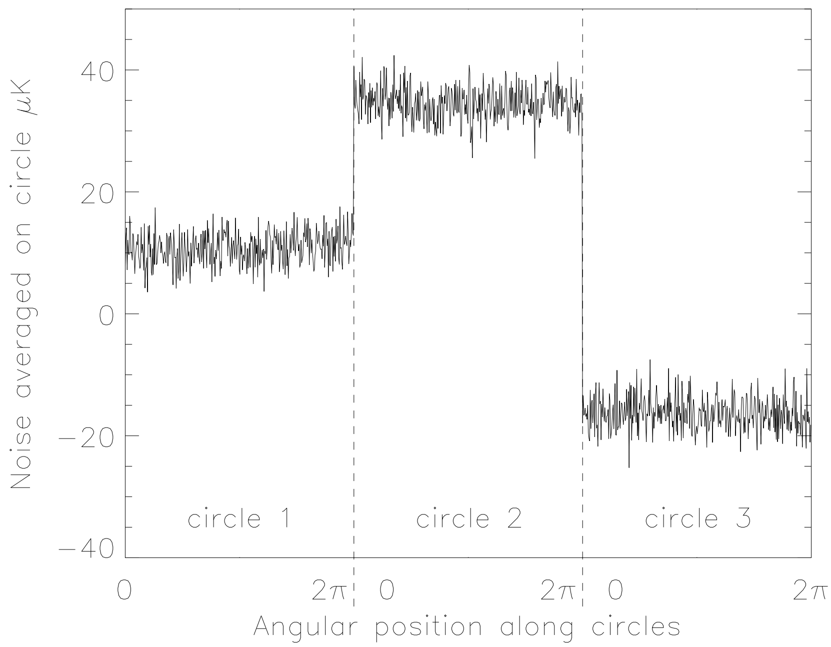


for each polarimeter.

After averaging, low-frequency drifts...

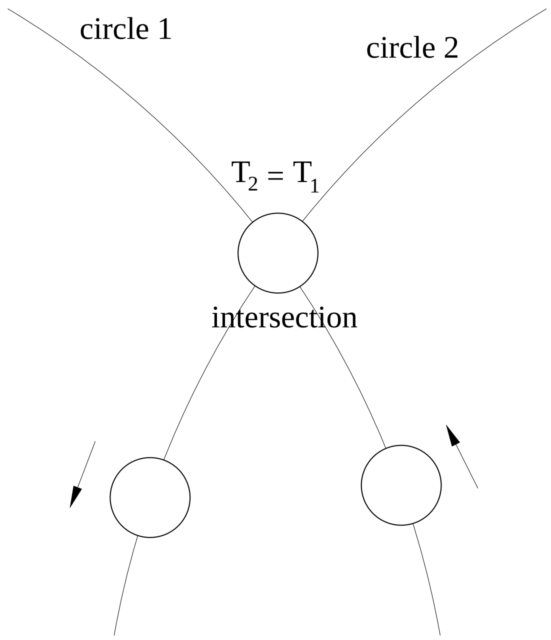


...transform as offsets:



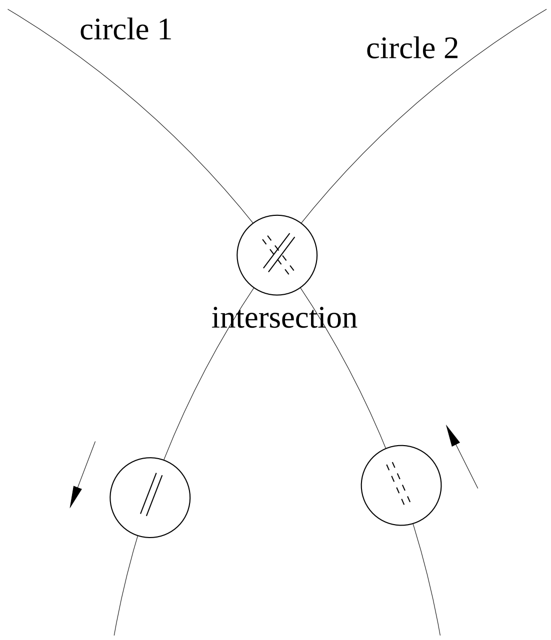
And we use the intersections:

for temperature measurements,



BUT for polarized measurements,

$$m_p = \frac{1}{2}\left(I + Q\cos 2\alpha_p + U\sin 2\alpha_p\right)$$

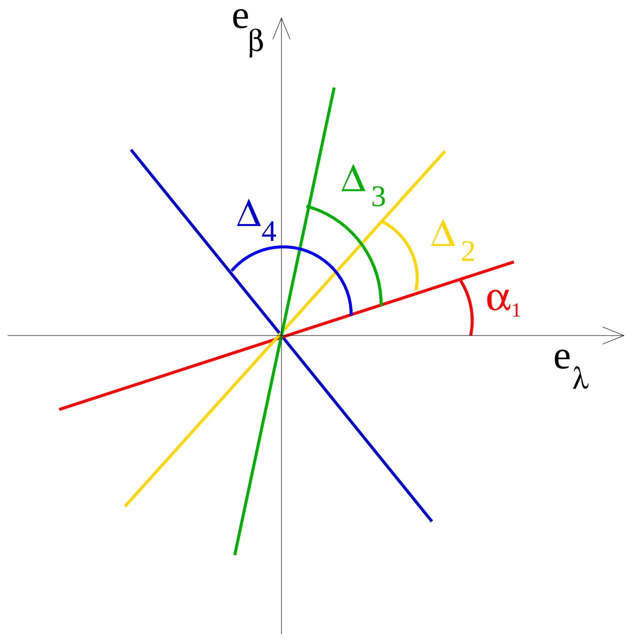


A polarimeter measures:

$$m_p = \frac{1}{2}\left(I + Q\cos 2\alpha_p + U\sin 2\alpha_p\right)$$

with

$$\alpha_p = \alpha_1 + \Delta_p$$



For h polarimeters, we can write:

$$M = A\ R(\alpha_1)\ S$$

where

A	caracterizes the layout of the polarimeters
$R(\alpha_1)$	caracterizes the rotation of the focal plane
S	are the fixed Stokes parameters.

We get finally:

$$M = \begin{bmatrix} 1 & 1 & 0 \\ 1 & \cos 2\Delta_2 & \sin 2\Delta_2 \\ \vdots & \vdots & \vdots \\ 1 & \cos 2\Delta_h & \sin 2\Delta_h \end{bmatrix}$$

$$\times \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 2\alpha_1 & \sin 2\alpha_1 \\ 0 & -\sin 2\alpha_1 & \cos 2\alpha_1 \end{bmatrix}$$

$$\times \begin{pmatrix} I \\ Q \\ U \end{pmatrix}$$

The model of the polarized measurements is:

$$M = O + A\ R(\alpha_1)\ S + noise$$

offsets due
to the low-frequency
noise

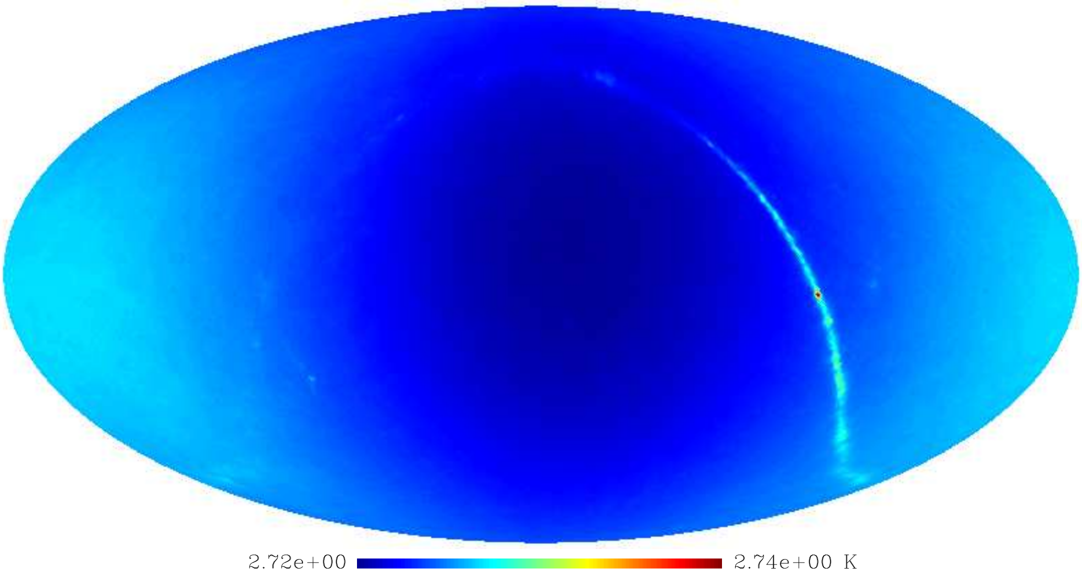
contribution
of the sky
we want to extract

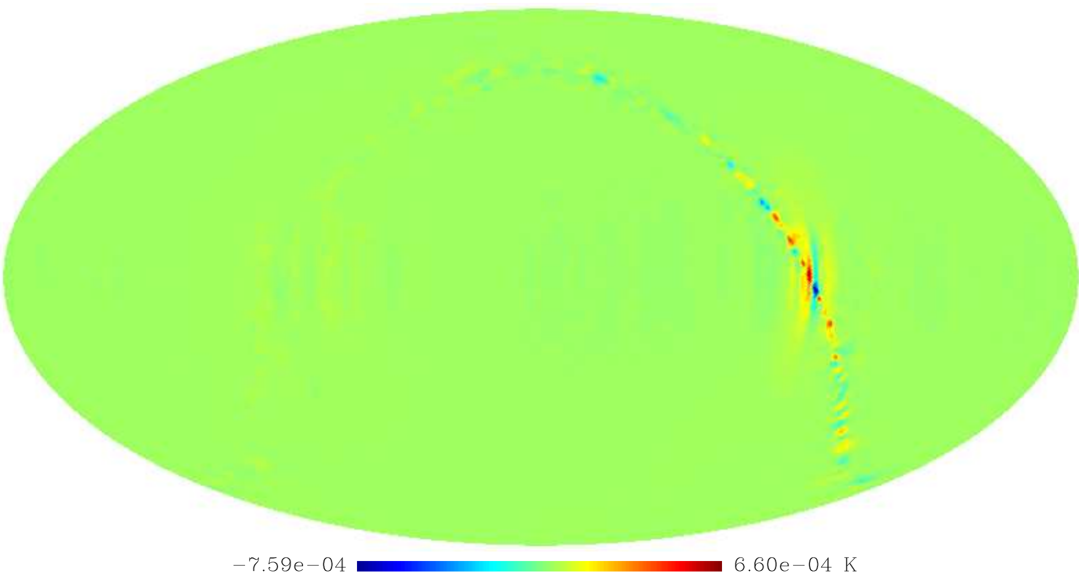
The offsets are computed minimizing a χ^2:

$$\chi^2 = \sum_{\text{intersections}} (M - O - A\ R(\alpha_1)\ S)^T$$
$$N^{-1}\,(M - O - A\ R(\alpha_1)\ S)$$

Test of destriping: simulations.

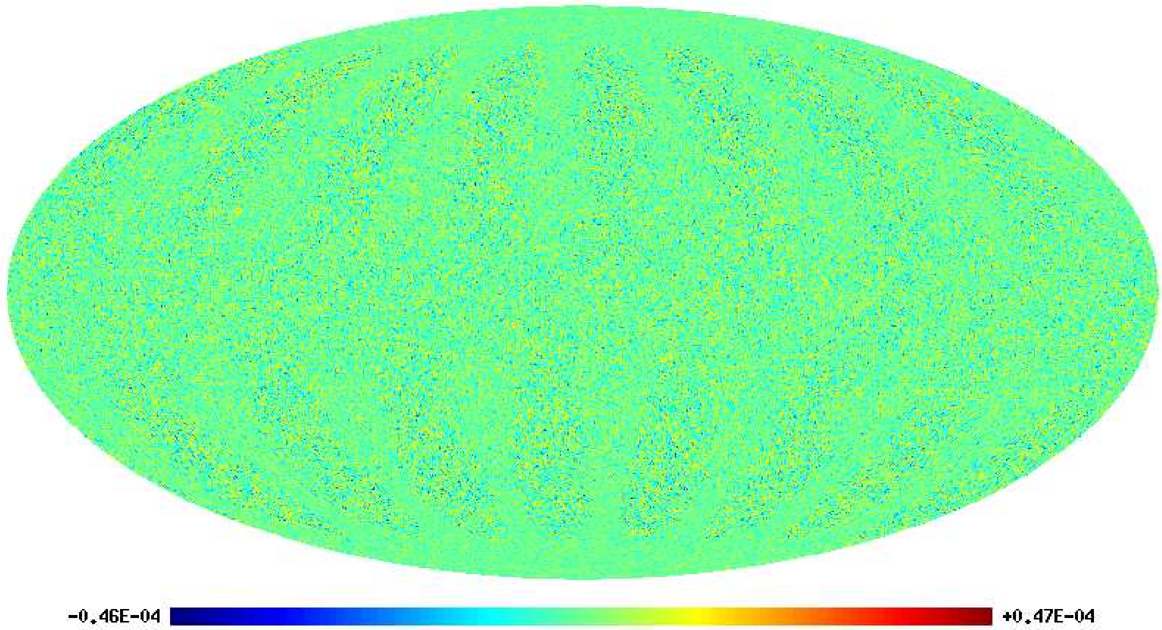
Simulated sky maps



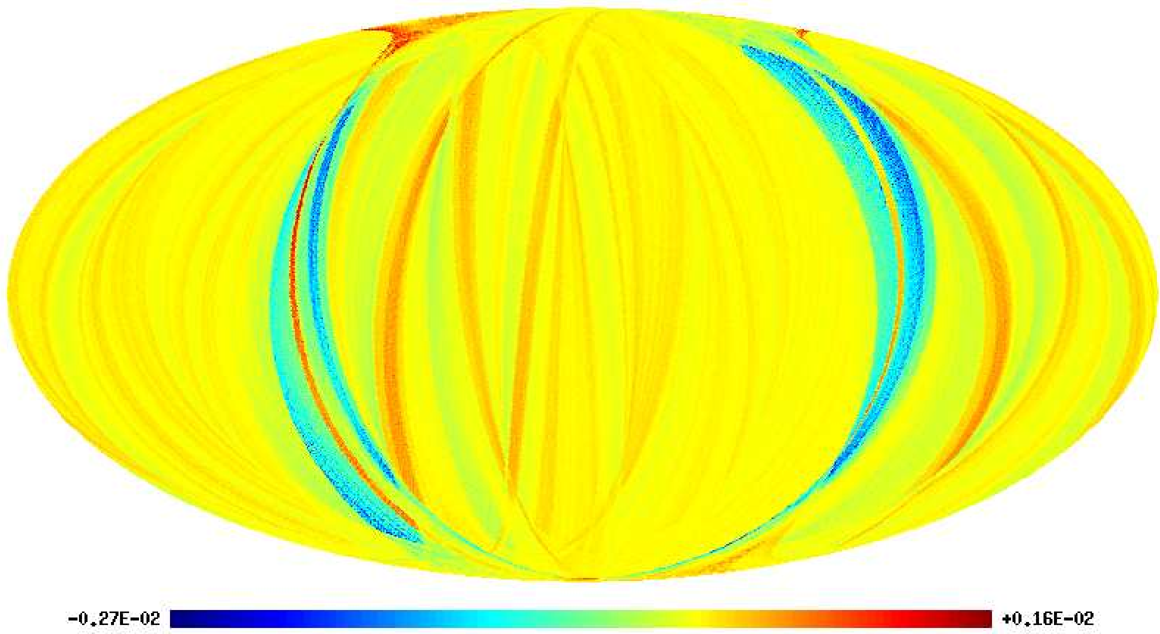


Results:

White noise:

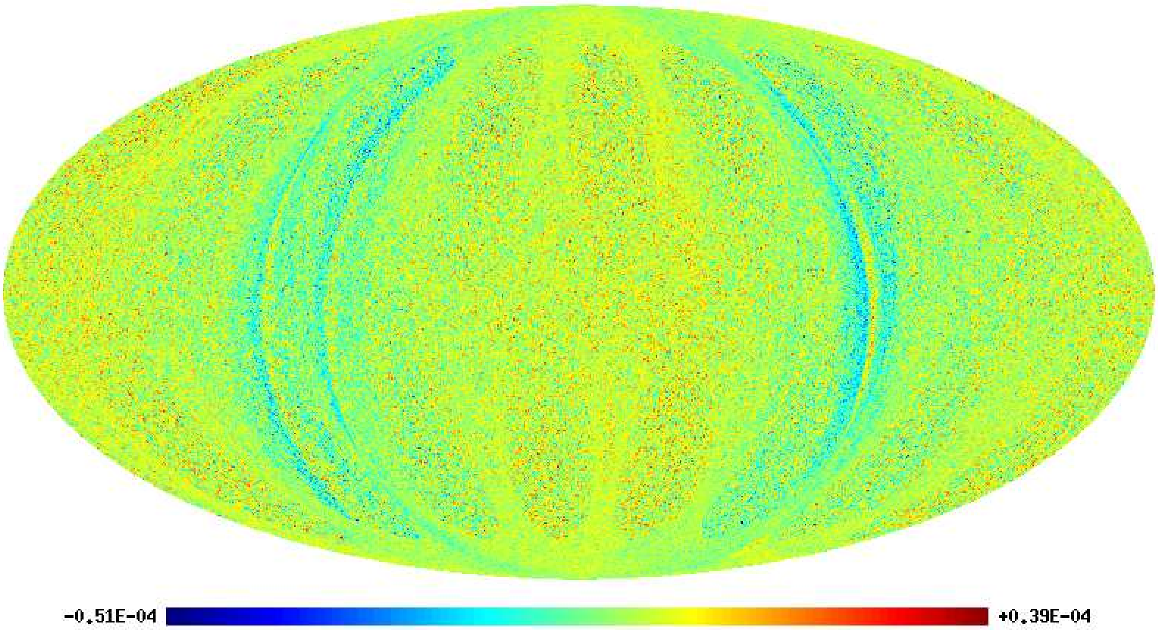


Undestriped:

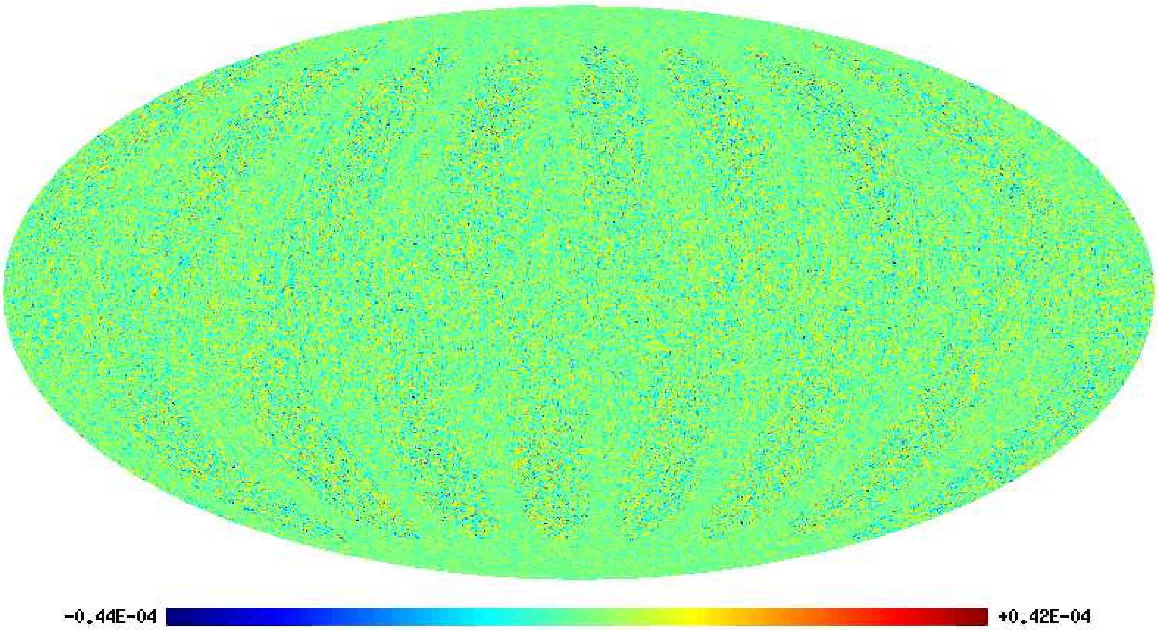


Results:

Zero average:

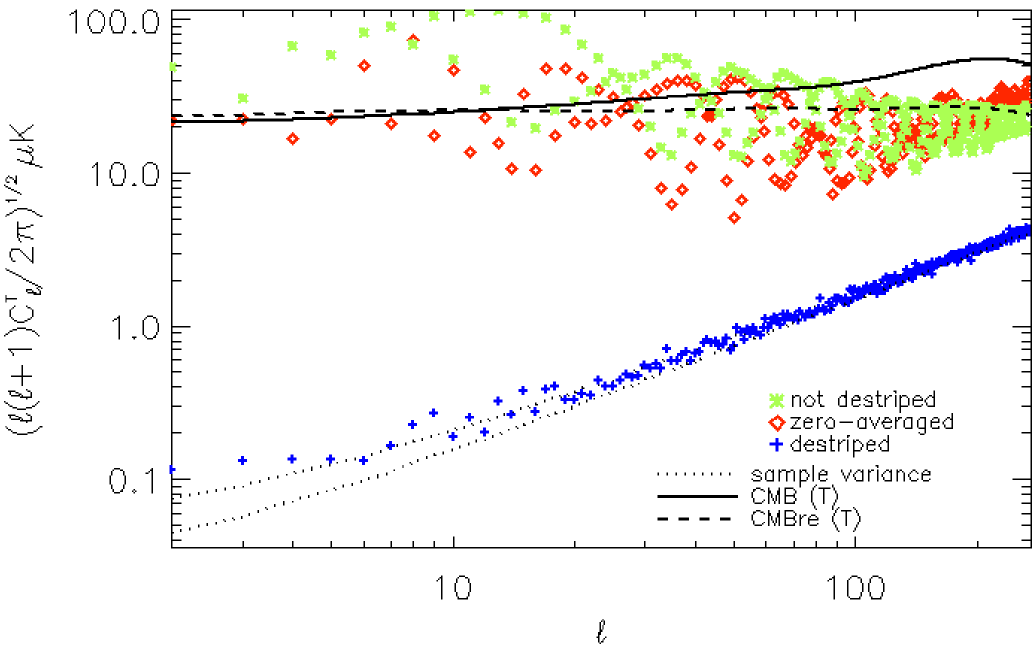


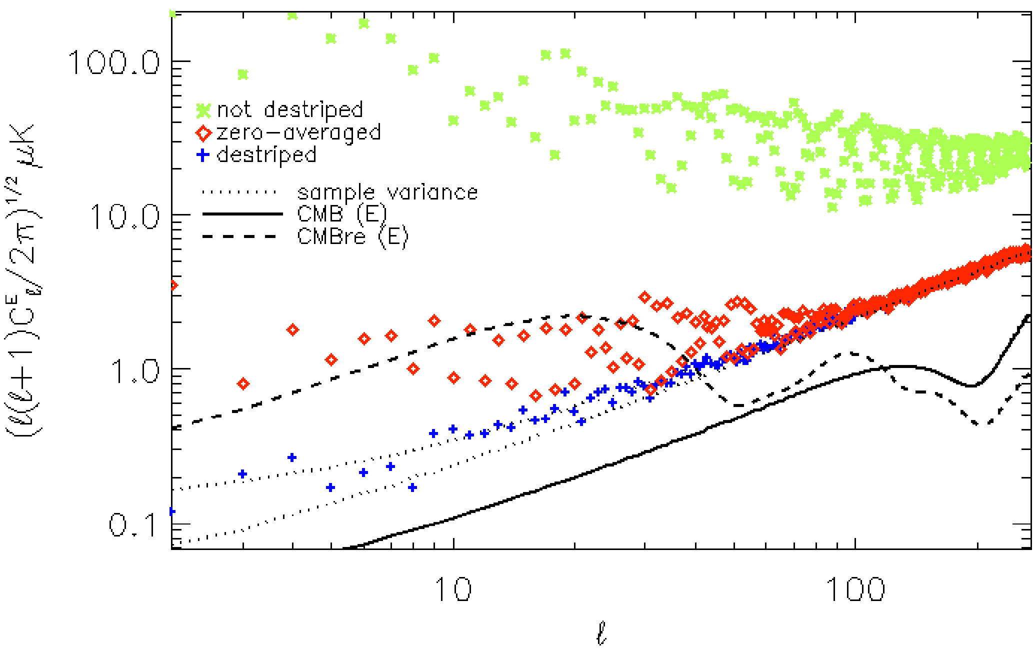
Destriped:



Statistical analysis of destriping

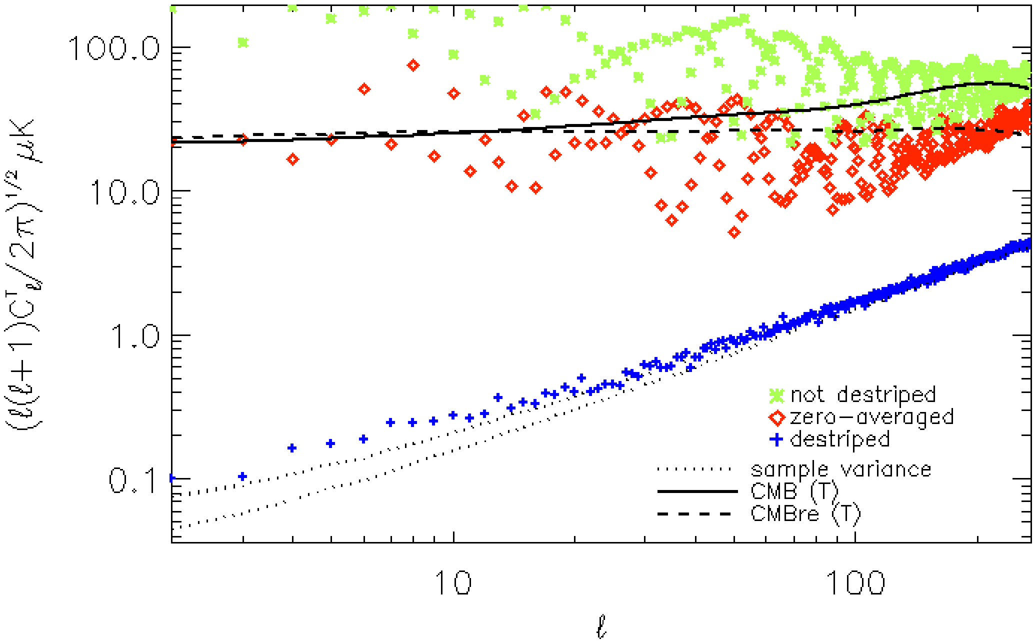
$f_{\rm knee}/f_{\rm spin}$=1

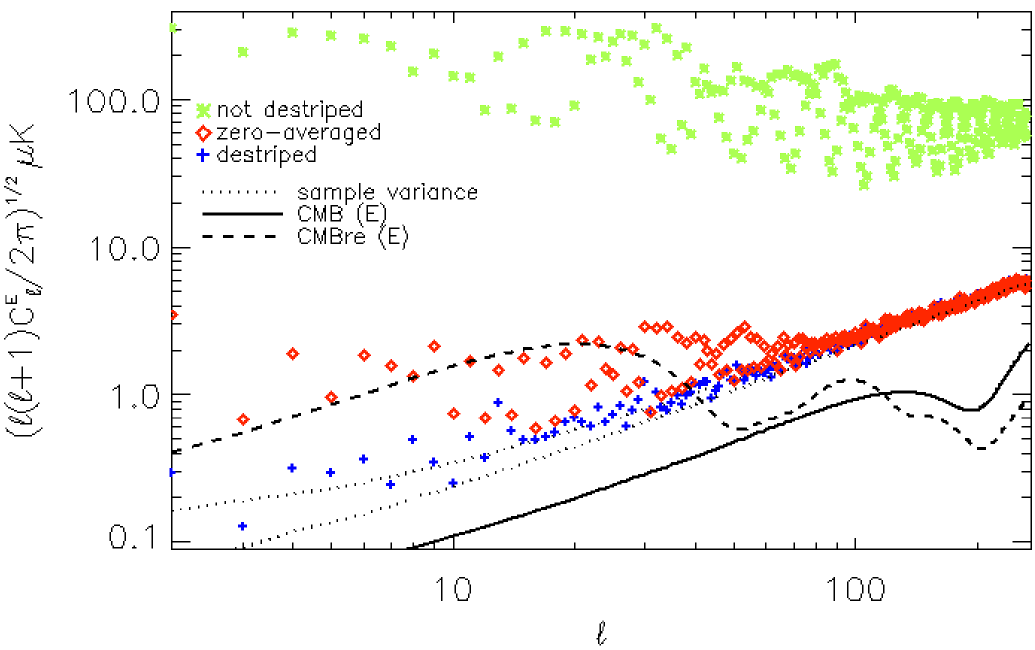




Statistical analysis of destriping

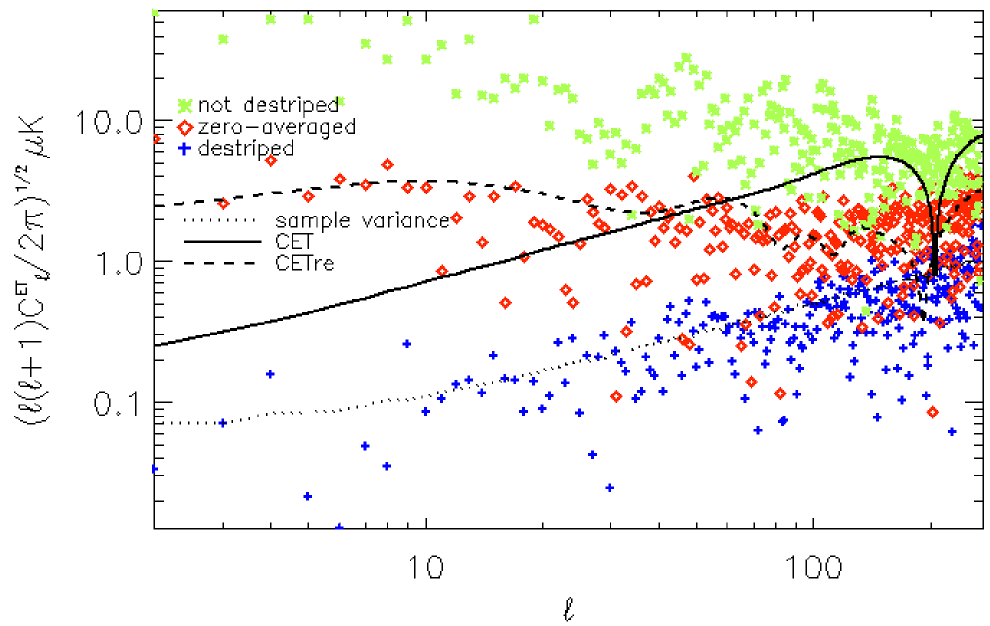
$f_{\text{knee}}/f_{\text{spin}}=5$



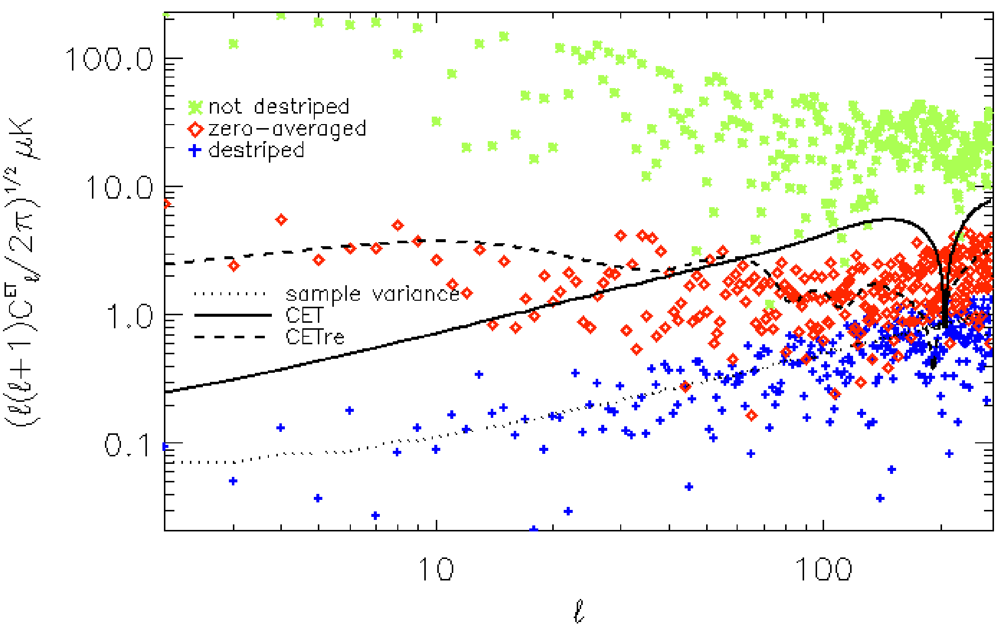


Statistical analysis of destriping

$f_{\rm knee}/f_{\rm spin}$=1



$f_{\rm knee}/f_{\rm spin}$=5



Improvements

It is now possible to fit any function, even a template.

The model of the measurement becomes:

$$M = A\ R(\alpha_1)\ S + \sum_{\ell=0}^{n_{\rm fit}-1} a_\ell\, f_\ell(\phi)$$

For instance:

$$f_0 = 1 \qquad \text{to fit the offset}$$

$$\left.\begin{array}{lcl} f_1 & = & \cos(\phi) \\ f_2 & = & \sin(\phi) \end{array}\right\} \quad \text{to fit the residual drifts}$$

The size of the system to invert is small: $3n\,(2\,n_{\rm fit} - 1)$

Striping estimator

$$\frac{\sigma(a_{\ell\ell})}{\sigma(a_{\ell 0})}$$

must be equal to 1 for a uniform sky covering.

Method	$f_{\rm knee}/f_{\rm spin}$	T	E	B
white noise	0	1	1	1
destriped	**0.5**	**1.19**	**1.05**	**1.03**
zero-averaged	0.5	51.9	9.23	3.64
undestriped	0.5	6.98	7.04	15.2
destriped	**1**	**1.24**	**1.12**	**1.19**
zero-averaged	1	52.2	9.91	3.95
undestriped	1	10.7	10.9	7.51
destriped	**2**	**1.26**	**1.32**	**1.23**
zero-averaged	2	49.5	10.2	3.85
undestriped	2	6.41	9.97	8.18
destriped	**5**	**1.35**	**1.39**	**1.38**
zero-averaged	5	49.8	10.4	3.99
undestriped	5	11.3	8.24	12.4

Conclusions

- We can lower the effect of low-frequency drifts up to the white noise level for $f_{\rm knee}/f_{\rm spin} \leq 1$ (check for $f_{\rm knee}/f_{\rm spin} \geq 1$ using the new algorithm).
- The system is small $\longrightarrow$ fast inversion.
- The next step is to include the contribution of the polarized lobes.

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