Deliverable 4.2:

Tuned MADAM module

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Revision History

Version	Authors	Date	Changes
1.0	Anna-Stiina Suur-Uski Elina Keihänen	February 26th, 2018	Initial Version

Contents

Overview

Map-making in a standard CMB analysis chain compresses the time-ordered data into sky maps. One example map is shown in the left panel of Figure 1. The pre-processed data, however, contains contributions from instrumental noise, which if left untreated will alter the statistical properties of the resulting maps.

For Planck LFI radiometers the noise model consists of two independent components: white (uncorrelated) and 1/*f* (correlated) noise (J. Delabrouille, A&A Supp. Ser. 127:555-567, 1998). The untreated 1/*f* noise component shows up in the resulting maps as stripy features, as illustrated in the right panel of Figure 1. Hence, in addition to visualising and compressing data, a proper map-making algorithm aims to remove the 1/*f* noise, while processing the CMB signal and white noise as little as possible.

Map-making step in the BeyondPlanck work is performed with the Madam map-maker code (E. Keihanen et al, A&A, 510: A57, 2010). The code is fully functional, and Madam3.8 has been the main map-making tool of the LFI DPC. Madam map-maker is based on a destriping principle (C. Burigana et al., astro-ph/9906360, 1999), where the 1/*f* noise component is modelled by a sequence of constant offsets, called baselines. Further, the Madam map-maker is able to use a noise prior to constrain baseline amplitudes (E. Keihanen et al., A&A, 510, A57, 2010), which allows us to shorten the baseline length considerably and to remove the 1/*f* component more accurately.

We have integrated the Madam map-maker code (version 3.9.0) into the BeyondPlanck pipeline, and additionally tested and validated that the code is performing as expected.

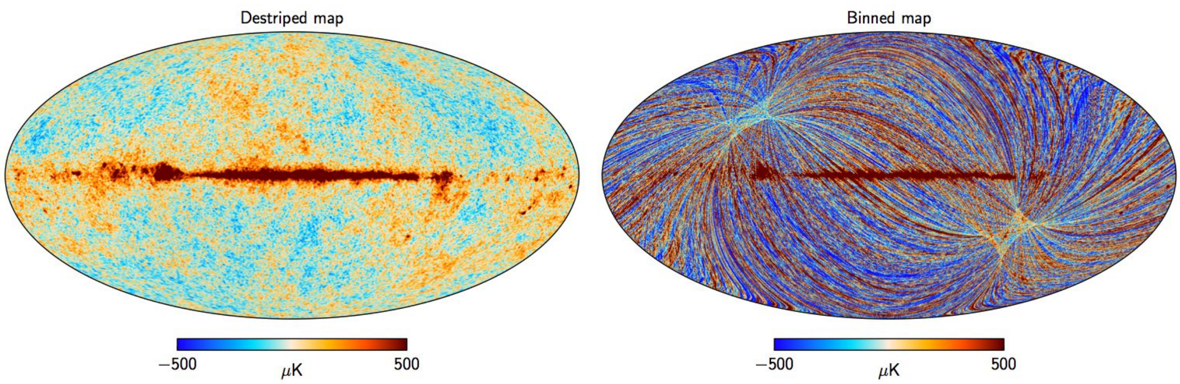

Figure 1: The effect of destriping on a simulated data set. *Left:* Destriped map. *Right:* Binned map. The binned map appears stripy due to the 1/*f* noise, while the destriping brings out the CMB and foreground signals. In reality the shown binned map is exaggeratedly stripy, as the pre-processing of the real data already removes correlations on time scales longer than a pointing period. Maps are shown in Galactic coordinates.

Madam as a part of the BeyondPlanck pipeline

Integrating the Madam map-maker into the BeyondPlanck pipeline required modifications especially to the data reading routines, as the format of the input data changed when the analysis moved from the LFI DPC environment to the Oslo Owl cluster. Now Madam map-maker is capable of reading input data in the HDF5 format.

We have also investigated if some of the Madam's parameters could be changed from the previously used values in the Planck LFI analysis to achieve either speed up in the processing or increase in the accuracy.

Software and compilation

Madam 3.9.0 is available in the BeyondPlanck GitLab repository

- https://gitlab.com/BeyondPlanck/repo/commits/master/madam

To compile Madam, the user must have access to the following compilers and libraries:

- Fortran MPI compiler, for instance Intel
- CFITSIO, https://heasarc.gsfc.nasa.gov/fitsio/fitsio.html
- FFTW, http://www.fftw.org/
- HDF5, https://support.hdfgroup.org/HDF5/

Options for the compilers and libraries are defined in the Makefile.

Following modules need to loaded before compiling:

- module load Intel_composer_xe/2017/1.132
- module load openmpi/Intel/2.1.1
- module load Intel_parallel_studio

The Madam code can be compiled as follows:

- cd <your_path>/madam
- make

The resulting executable is <your_path>/madam/madam

Usage

To run Madam one needs a parameter and a simulation file, which contains information about the dataset and detectors.

For creating a simulation file, we have a python script make_simufile_owl.py. Run by typing:

- module load python/3.6
- python make_simufile_owl.py

Inside the make_simufile_owl.py script the user must define the location of the detector pointing files (detpt_dir), the location of the data files (tod_dir), the RIMO file (rimo), and name of the output simulation file (f_out). All input data on the Owl cluster for the BeyondPlanck can be found from the directory:

- /mn/stornext/d14/bp/data

Example parameter file on the Owl cluster is:

- /mn/stornext/d14/bp/annastiina/HDF5_Madam/madam_DX12.par

We used this parameter file to crosscheck Madam3.9.0 results with the Planck LFI legacy maps (DX12).

Full Madam manual that explains for example all the possible input parameters, is available from the BeyondPlanck wiki:
https://gitlab.com/BeyondPlanck/repo/uploads/b16319d097c852b8dff8887d0533e18f/manual.pdf

Madam is run on Owl as follows:

- mpiexec -n N <your_path>/madam/madam madam.par > madam.out

The number of cores, N, may be set to any number, typically the same number of cores as is available on the compute nodes employed for the analysis.

Most common outputs are:

- File_map (Destriped map)
- file_hit (optional) (Hit count map)
- file_binmap (optional) (Binned map)
- file_cov (optional) (White noise covariance)
- file_4Dmap (optional) (Input to deconvolution, WP5)

Testing and validating

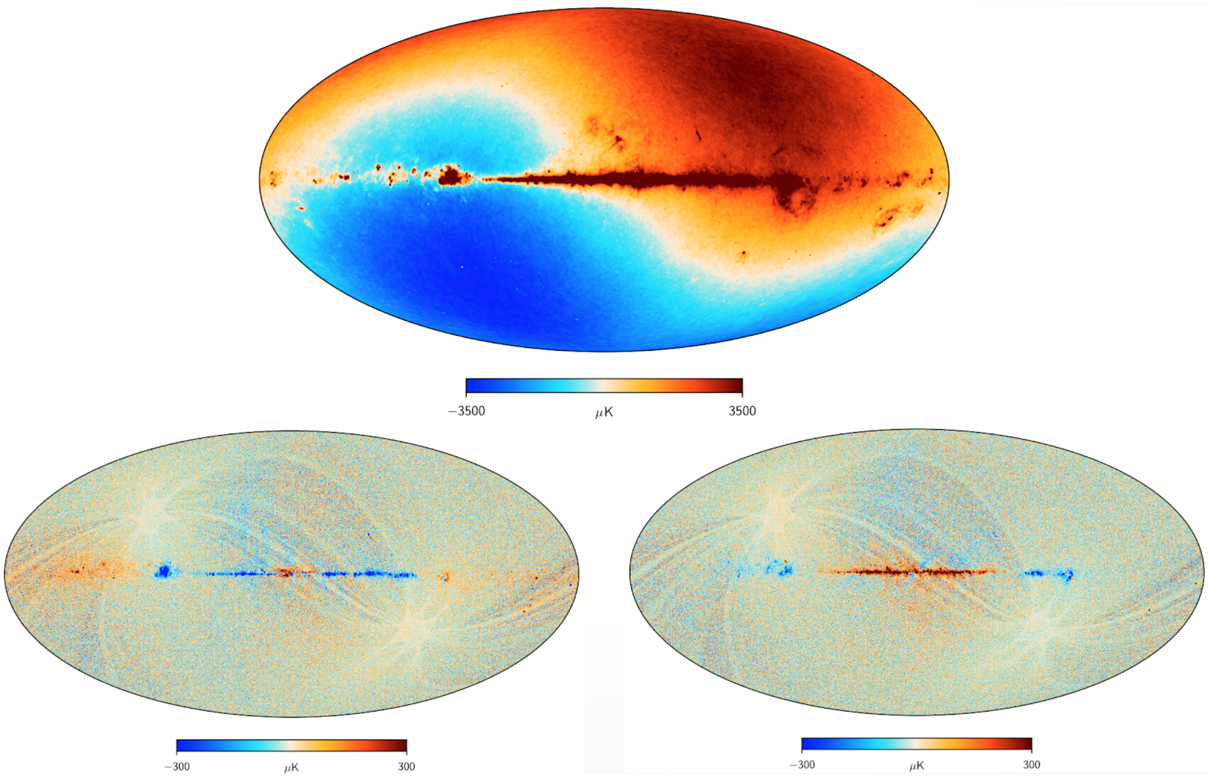

Figure 2: *Top:* The 30GHz map for the full mission calculated with Madam3.9.0 for intensity. *Bottom: Q* and *U* components.

We have made number of test runs to validate the Madam3.9.0. For example:

- We calculated maps from the same data either in HDF5 format with Madam3.9.0 or in FITS format with Madam3.8.3. The difference of these maps was found to be identically zero.
- We calculated a map using exactly the same runtime parameters as used in the DX12 map-making on the LFI DPC. We compared the new map with the Planck LFI legacy map. The difference was found to be small, of the order of 10^-6 K.
- We compared the hit count maps from the previous step. The difference was found to be identically zero. This means that we assign observations to the same pixels, and employ the same quality flags.

In Figure 2 we show example maps from the calibrated data calculated using the Madam3.9.0.

Madam3.9.0 is ready to be used in the BeyondPlanck pipeline.

References

J. Delabrouille. Analysis of the accuracy of a destriping method for future cosmic microwave background mapping with the PLANCK SURVEYOR satellite. Astron. Astrophys. Supp. Ser. 127:555-567, 1998

E. Keihanen et al. Making cosmic microwave background temperature and polarization maps with MADAM, Astron. Astrophys., 510: A57, 2010

C. Burrigana et al. A preliminary study on destriping techniques of PLANCK/LFI measurements versus observational strategy, astro-ph/9906360, 1999