Overview of LFI maps generation and their characteristics

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Outline

Operations

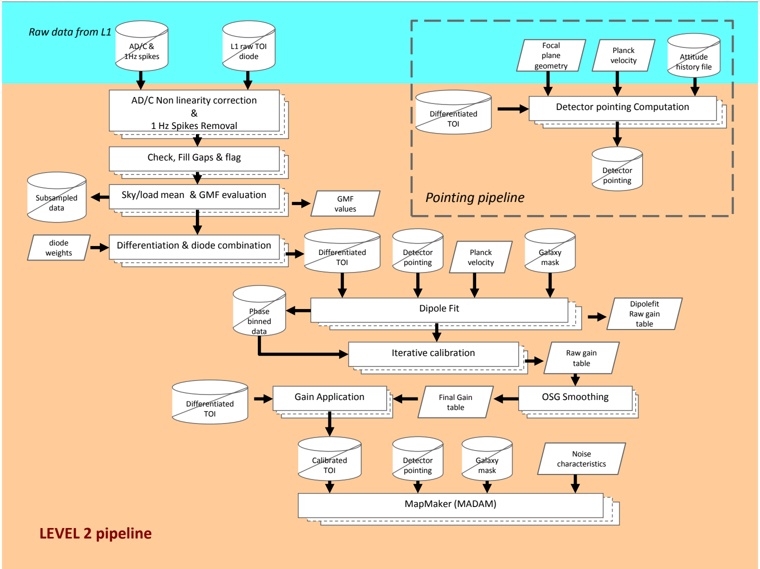
- *Planck* was launched on 14 May 2009 and the current data release includes temperature maps based on the first 15.5 months of observations
- *Planck* is still alive and LFI is currently taking data
  - HFI was switched off on January 2012, beyond the *nominal* period and now is supporting LFI providing essential H/K telemetry (e.g. 4K cooler)
  - LFI is expected to continue at least till September 2013
- Data are of incredible quality!

Data Processing Overview

PLANCK

- DPC approaches data reduction with specific tasks aiming to estimate and correct instrumental systematic effects
- There are three main logical levels:
  - Level 1: H/K and Science telemetry from the satellite are transformed into raw timelines and stored into dedicated databases with the associated time information
  - Level 2: instrument information is gathered and ingested into the Instrument Model, removal of systematic effects, flag data of suspected quality, photometric calibration and creation of maps and ancillary products
  - Level 3: more science here with component separation, power spectra estimation and extraction of cosmological parameters
- Each step is internally validated (with dedicated sims) and most of the DPC work is spent cross-checking internally and between the two instruments

LFI pipeline

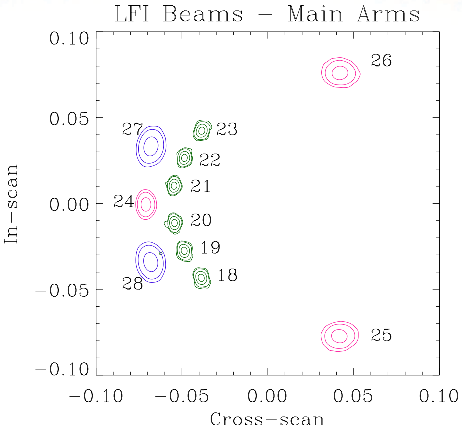


Flagged data

	30 GHz	44 GHz	70 GHz
Missing [%]	0.00014	0.00023	0.00032
Anomalies [%]	0.82220	0.99763	0.82925
Manoeuvres [%]	8.07022	8.07022	8.07022
Usable [%]	91.10744	90.93191	91.10021

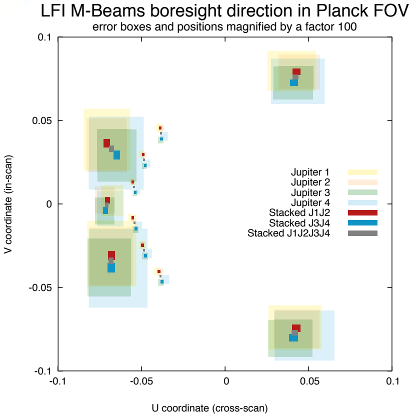
- During L1 and L2 pipeline all data are checked sample-by-sample to discard, flag all unusable samples and data acquired during manoeuvres and special operations (e.g. Sorption cooler switch-over)
- About 1% of the data are discarded due to instrument anomaly

Beams reconstruction



- Beams contours (-20dB) from planet transit. From S/C attitude and this geometrical calibration, pointing for each horn is reconstructed

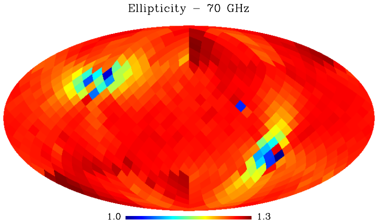
Detector Pointing



- Pointing reconstruction: error smaller that $0.5'$. Several corrections applied: stellar aberration and wobble angle (thermoelastic deformation changing the relative orientation between start-tracker and reference body frame).

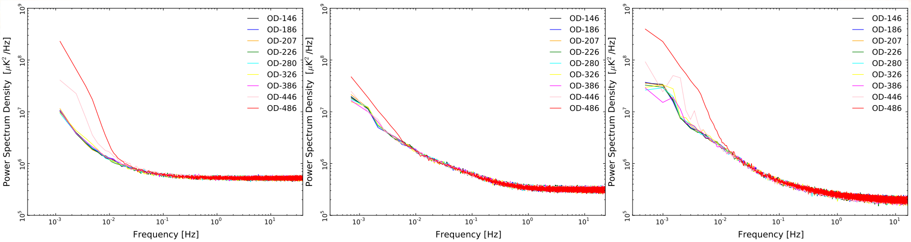
Effective Beams

Band	FWHM [′]	e	Ω [arcmin^2]
30	32.239±0.013	1.320±0.031	1189.51±0.84
44	27.01±0.55	1.034±0.031	833±32
70	13.252±0.033	1.223±0.026	200.7±1.0



- Scanning beams are used to compute effective beams which gives pixel-by pixel the beam shape projected in the sky when scanning strategy is accounted for. Fundamental for point source extractions and computation of beam window function

LFI TOI Noise Estimation

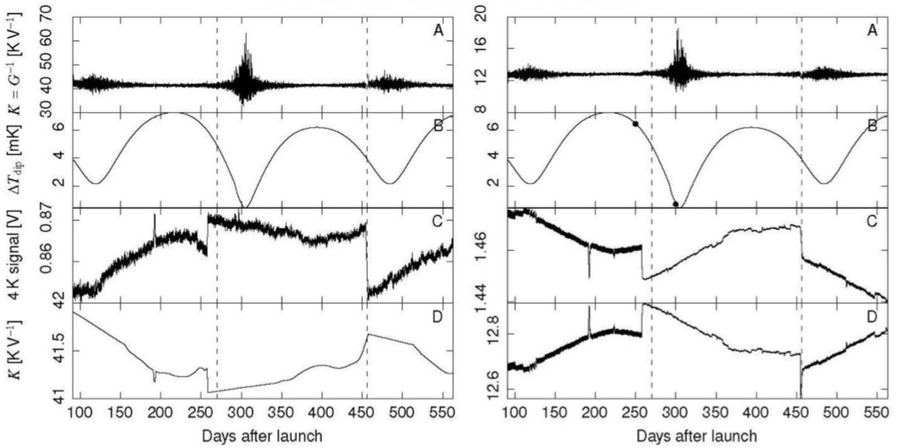


- Noise estimation is used as a diagnostic tool and provide information for Monte Carlo Simulations. Determines also the correct horn weights used during the map-making process. Noise pipeline is checked against noise derived from HR maps and it is compatible at 1% level

Photometric Calibration

- This is the most important and critical aspect of data reduction pipeline. The LFI one works as follows
  - estimate dipole amplitude and alignment of dipole for any direction
  - create the expected level of the dipole signal accounting for the full-beam shape
  - fit real data with dipole with iterative approach (raw gains)
  - filter raw gains or use 4K to calibrate data
  - Calib. Accuracy estimated to be $\sim$ 0.82% (30), $\sim$0.55% (44) and $\sim$0.62% (70)

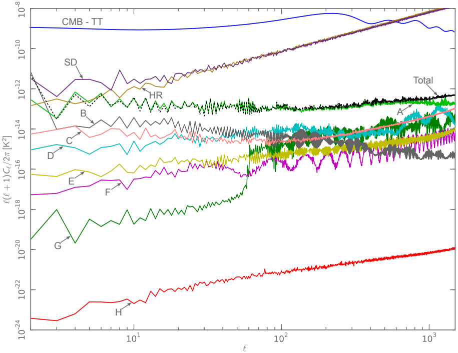
Photometric Calibration



Map-making

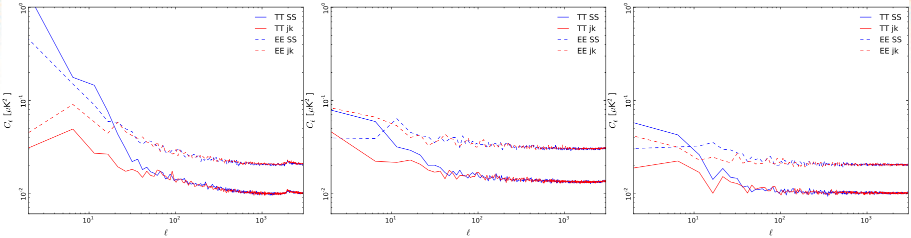
- Calibrated TOI for each radiometer are input of `madam` map-making code, together with pointing data
- The algorithm is a maximum-likelihood destriping and estimates in this fashion the amplitude of the $1/f$-noise baseline, subtract from the timelines and then simply bins the resulting TOI into a map
- Maps produced at different levels:
  - Frequency maps, HR maps and Survey maps
  - Low resolution maps used for the computation of the noise covariance matrix

Systematic effecs



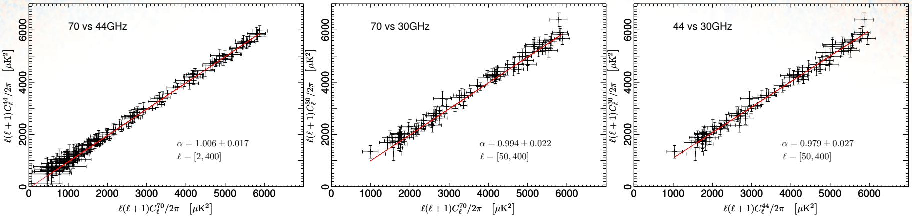
- Two strategies for systematic effects analysis:
  - Null tests: primary tool to see systematic effect residual w.r.t. white noise level
  - Sims: Assess their impact on TOI using in-flight H/K data. This approach provides a powerful tool to check for systematics

LFI Internal Validation - Null tests



- Quality of LFI maps is assessed and verified by a set of null-tests in an almost automatic way
- Several data combination (radiometer, horn-pairs, frequency) on different time-scales (1 hour, survey, full-mission): difference at horn level at even/odd surveys clearly reveals side lobe effect
- Null-test power spectra are used to check total level of systm. effects to be compared w.r.t. white noise level and systematic effects analysis

LFI Internal Validation - Check Spectra



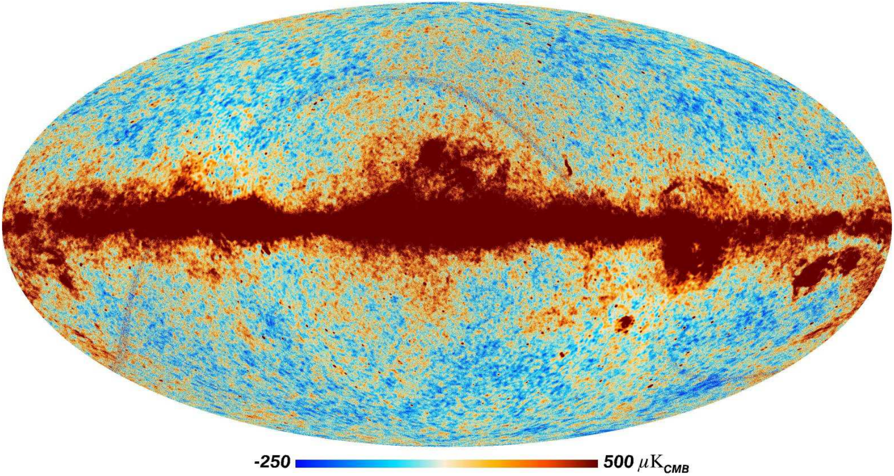
- Compute power spectra in multipole range around the first acoustic peak removing the unresolved point source contributions. Spectra are consistent within errors. 30 and 44/70 have different approaches to gain applied
- Hausman test assess consistency at 70 GHz showing no statistically significant problem
- Spectra from horn-pairs and from all 12 radiometers: χ^2 analysis shows compatibility with null-hypothesis

Maps Characteristics

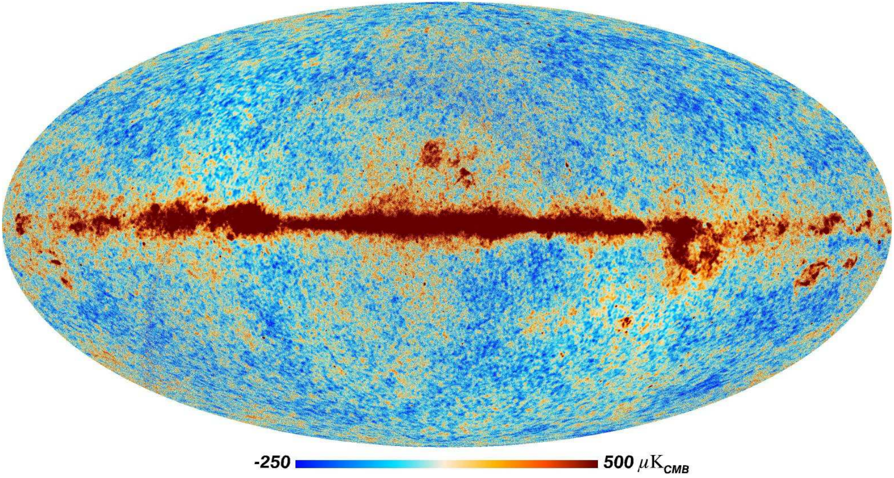
Uncertainty	Applies to	Method
Gain calib	All sky	*WMAP* dipole
Zero level	All sky	Galactic Cosecant model
Beam	All sky	GRASP models via FeBecop
CC	non-CMB	ground/flight bandpass leakage
Resid. Sys	All sky	Null-tests

Property	30	44	70
Frequency [GHz]	28.4	44.1	70.4
Noise rms/pixel [$\mu K_{\rm CMB}$]	9.2	12.5	23.2
Gain Uncert	0.82%	0.55%	0.62%
Zero Level Uncert [$\mu K_{\rm CMB}$]	± 2.23	± 0.78	± 0.64

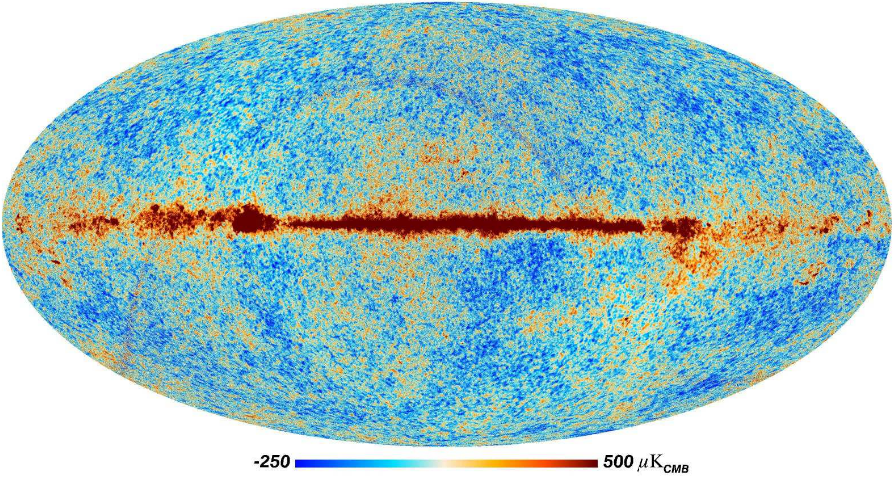
Planck-LFI 30 GHz



Planck-LFI 44 GHz



Planck-LFI 70 GHz



Future Steps & Conclusions

- Maps and other products are of very high quality and consistency
- Next goal will be the analysis of polarisation data. This implies the following steps:
  - 4π beam in calibration based on in-band response
  - Removal of Galactic Straylight
  - Assessment of expected systematics in polarisation