Planck

Report on the status of the mission

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Outline

- CMB
- The Planck satellite
- Data processing center
- Expectations from Planck
- Planck data
CMB anisotropies

\[ T(n), Q(n), U(n), V(n) \]

\[ a_{T \ell m}, a_{E \ell m}, a_{B \ell m} \]

\[ C_l = \sum_m (a_{\ell m}^{T,E,B})(a_{\ell m}^{T,E,B})^*/2(l+1) \]
CMB angular power spectrum

Angle $\approx \frac{200}{\ell}$ degrees
CMB angular power spectrum

Angle \approx \frac{200}{\ell} \text{ degrees}
Measured CMB anisotropies

Angle $\approx 200/\ell$ degrees
CMB angular power spectrum

Angular Scale

\[ \langle EE \rangle \]

boomerang

acbar

WMAP

quad
Cosmological concordance model
Cosmological concordance model
Cosmological concordance model
The Planck satellite

Source: Planck scientific program bluebook, available at www.rssd.esa.int/Planck
Planck

- Hardware: ~600 ME, third generation CMB probe, ESA medium size mission, NASA (JPL, Pasadena) contribution on cooling systems
- Low Frequency Instrument (LFI, Nazareno Mandolesi PI, instrument design and construction supervised by Marco Bersanelli) based on radiometer technology operating at three frequency channels, 30, 44, 70 GHz
- High Frequency Instrument (HFI, Jean-Loup Puget PI) based on bolometer technology, operating at 100, 143, 217, 353, 545 GHz
- About 16 years (1993-2009) of design and construction
The Planck focal plane
Planck detectors

<table>
<thead>
<tr>
<th>Instrument Characteristic</th>
<th>Center Frequency [GHz]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
</tr>
<tr>
<td>InP HEMT Detector technology</td>
<td>MIC</td>
</tr>
<tr>
<td>Detector temperature</td>
<td></td>
</tr>
<tr>
<td>Cooling system</td>
<td>2</td>
</tr>
<tr>
<td>Number of feeds</td>
<td>33</td>
</tr>
<tr>
<td>Angular resolution [arcminutes FWHM]</td>
<td>6</td>
</tr>
<tr>
<td>Effective bandwidth [GHz]</td>
<td></td>
</tr>
<tr>
<td>Sensitivity [mK Hz$^{-1/2}$]</td>
<td>0.17</td>
</tr>
<tr>
<td>System temperature [K]</td>
<td>7.5</td>
</tr>
<tr>
<td>Noise per 30'$'$ reference pixel [$\mu K$]</td>
<td>6</td>
</tr>
<tr>
<td>$\Delta T/T$ Intensity $^b$ [$10^{-6}$ $\mu K/K$]</td>
<td>2.0</td>
</tr>
<tr>
<td>$(\Delta T/T)$ Polarisation (Q and U) $^b$ [$\mu K/K$]</td>
<td>2.8</td>
</tr>
<tr>
<td>Maximum systematic error per pixel [$\mu K$]</td>
<td>&lt; 3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instrument Characteristic</th>
<th>Center Frequency [GHz]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Spectral resolution $\nu/\Delta \nu$</td>
<td>3</td>
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<tr>
<td>Detector technology</td>
<td>Spider-web and polarisation-sensitive bolometers</td>
</tr>
<tr>
<td>Detector temperature</td>
<td>0.1 K</td>
</tr>
<tr>
<td>Cooling system</td>
<td>20 K Sorption Cooler + 4 K J-T + 0.1 K Dilution</td>
</tr>
<tr>
<td>Number of spider-web bolometers</td>
<td>0</td>
</tr>
<tr>
<td>Number of polarisation-sensitive bolometers</td>
<td>8</td>
</tr>
<tr>
<td>Angular resolution [FWHM arcminutes]</td>
<td>9.5</td>
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<tr>
<td>Detector Noise-Equivalent Temperature [$\mu Ks^{0.5}$]</td>
<td>50</td>
</tr>
<tr>
<td>$\Delta T/T$ Intensity $^b$ [$10^{-6}$ $\mu K/K$]</td>
<td>2.5</td>
</tr>
<tr>
<td>$\Delta T/T$ Polariation (U and Q) $^b$ [$10^{-6}$ $\mu K/K$]</td>
<td>4.0</td>
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<tr>
<td>Sensitivity to unresolved sources [mJy]</td>
<td>12.0</td>
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<tr>
<td>$\nu$SZ per FOV [$10^{-6}$]</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Planck frequency coverage
The Planck launch, May 14th, 2009
Planck cooling
Data processing center
Planck contributors

Davies
Berkeley
Pasadena

Minneapolis
Cambridge
Brighton

Toulouse
Santander
Oviedo

Paris
Milan
Bologna

Oxford
Trieste
Padua

Rome
Helsinki
Copenhagen

Munich
Heidelberg

Bucarest

Planck contributors
Planck data processing centers

Paris, Trieste
Data flow and analysis levels

- **Level 1**, telemetry, timeline processing, calibration
- **Level 2**, map-making
- **Level 3**, multi-frequency analysis, production of Galactic, extra-Galactic and CMB science products

Mission Operation Center, Darmstadt

Trieste
LFI timeline processing and map-making

Paris
HFI timeline processing and map-making

Map exchange, separation of astrophysical foreground and backgrounds, Galactic, extra-Galactic astrophysics, CMB science
Trieste, time ordered data processing, component separation, cosmological parameters

Rome, GLS map-making, power spectra, cosmological parameters

Bologna, beam reconstruction, power spectra, cosmological parameters

Milano, calibration, component separation

Helsinki, destriper map-making

Padova, component separation

Berkeley, simulations

The LFI DPC
Planck DPC facilities

- DPC people physically in Trieste are about 20 at OATs and SISSA
- The data are hosted on two computers, ENT (OATs, front-end database and computing resource, 256 CPUs, hundreds of GB RAM, tens of TB disk space), HG1 (SISSA, computing resources, 160 CPUs, hundreds of GB RAM, tens of TB disk space)
Planck milestones

- May 14th, 2009, launch, the High Frequency Instrument (HFI, bolometers) is on
- June 1st, 2009, active cryogenic systems are turned on
- June 8th, 2009, the Low Frequency Instrument (LFI, radiometers), is turned on
- Summer 2009, Planck gets to L2, survey begins, 14 months
- 2 years of proprietary period and data analysis
- Early papers on extra-Galactic astrophysics, early 2011
- Complete results including cosmology, end of 2012
- Mission extended! Survey doubled, beginning October 2010, ending end of 2011
Expectations from Planck

Source: Planck scientific program bluebook, available at www.rssd.esa.int/Planck
Planck deliverables

- All sky maps in total intensity and polarization, at 9 frequencies between 30 and 857 GHz
- Angular resolution from 33' to 7' between 30 and 143 GHz, 5' at higher frequencies
- S/N ≈ 10 for CMB in total intensity, per resolution element
- Catalogues with tens of thousands of extra-Galactic sources
CMB imaging
CMB polarization
Probing next generation CMB goals
Cosmological parameters
Non-CMB Planck scientific deliverables

- \( \sim 10^3 \) galaxy clusters
- \( \sim 10^4 \) radio and infrared extra-Galactic sources
- Unprecedented insight into the physics of diffuse gas in the Galaxy, Galactic magnetic field, …
- …
Planck data
First light survey
First light survey
First light survey
First year survey

The Planck one-year all-sky survey

(c) ESA, HFI and LFI consortia, July 2010
First year survey

The Planck one-year all-sky survey
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