





Planck unveils the Cosmic Microwave Background



The Planck mission

J. A. Tauber European Space Agency on behalf of the Planck Collaboration



The Planck project:



- First proposed to ESA in 1993 as two separate satellites
 - COBRAS
 - SAMBA
- COBRAS/SAMBA selected in 1996 as the third medium-sized mission of the Horizons 2000 programme
 - HEMT radio arrays 30-125
 GHz @ 100 K
 - Bolometer arrays 143-857
 GHz @ 0.1 K
 - Launch in 2003





State of the art 1996

esa





From the Redbook...

European Space Agency

The Planck project,



- 1997-1998 were the "FIRST/Planck" years...
 - Eventually reason prevailed with the selection of the "Carrier" concept for Planck
 - Launch in 2007
- The designs for the LFI and HFI instruments were accepted in 1998
 - LFI cooled to 20 K
- In 2000, the ITT was issued to industry and eventually won by Alcatel (now Thales Alenia Space)
- In 2003,
 - loss of LFI 100 GHz channel
 - Gain of 100 GHz polarimetry



The finished product

D



The moment of glory



14 May 2009



2010: completion of two all-sky surveys



The Planck one-year all-sky survey





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Goal payload performance



Telescope	1.5 m (proj. aperture) aplanatic; shared focal plane; system emissivity 1%										
	Viewing direction offset 85° from spin axis; Field of View 8°										
Instrument		LFI		HFI							
Center Freq. (GHz)	30	44	70	100	143	217	353	545	857		
Detector Technology	HEM	T LNA a	arrays	Bolometer arrays							
Detector Temperature		~20 K		0.1 K							
Cooling Requirements	H ₂ sorption cooler			H ₂ sorption + 4 K J-T stage + Dilution cooler							
Number of Unpol.	0	0	0	0	4	4	4	4	4		
Detectors											
Number of Linearly	4	6	12	8	8	8	8	0	0		
Polarised Detectors											
Angular Resolution	33	24	14	9.5	7.1	5	5	5	5		
(FWHM, arcmin)											
Bandwidth (GHz)	6	8.8	14	33	47	72	116	180	283		
Average $\Delta T/T_{I}^{*}$ per	2.0	2.7	4.7	2.5	2.2	4.8	14.7	147	6700		
pixel [#]											
Average $\Delta T/T_{U,O}^*$ per	2.8	3.9	6.7	4.0	4.2	9.8	29.8				
pixel [#]											

^{*} Sensitivity (1 σ) to intensity (Stokes I) fluctuations observed on the sky, in thermodynamic temperature (x10⁻⁶) units, relative to the average temperature of the CMB (2.73 K), achievable after two sky surveys (14 months).

[#] A pixel is a square whose side is the FWHM extent of the beam.

* Sensitivity (1σ) to polarised intensity (Stokes U and Q) fluctuations observed on the sky, in thermodynamic temperature (x10⁻⁶) units, relative to the average temperature of the CMB (2.73 K), achievable after two sky surveys (14 months).



Current in-flight performance



- Array level: ~as expected from ground testing (exception: 100 GHz)
- Map level: at goal 143-353
 GHz; within a factor of 2 from goal 30-100 GHz
- Calibration: well within goal (1%) in CMB channels

			Scanni	ng Beam ^c	Noised		
CHANNEL	$N_{ m detectors}^{ m a}$	^v center ^b [GHz]	FWHM [arcm]	Ellipticity	$\frac{5 \text{ENS}}{[\mu \text{K}_{\text{RJ}} \text{ s}^{1/2}]}$	$\frac{1}{s^{1/2}} [\mu K_{CMB} s^{1/2}]$	
30 GHz	4	28.4	33.16	1.37	145.4	148.5	
44 GHz	6	44.1	28.09	1.25	164.8	173.2	
70 GHz	12	70.4	13.08	1.27	133.9	151.9	
100 GHz	8	100	9.59	1.21	31.52	41.3	
143 GHz	11	143	7.18	1.04	10.38	17.4	
217 GHz	12	217	4.87	1.22	7.45	23.8	
353 GHz	12	353	4.7	1.2	5.52	78.8	
545 GHz	3	545	4.73	1.18	2.66	0.0259 ^d	
857 GHz	4	857	4.51	1.38	1.33	0.0259 ^d	

		Frequency [GHz]								
Property	Applies to	30	44	70	100	143	217	353	545	857
Effective frequency [GHz]	Mean	28.4	44.1	70.4	100	143	217	353	545	857
Noise rms per pixel $[\mu K_{CMB}]$	Median	9.2	12.5	23.2	11	6	12	43		
$[MJy sr^{-1}]$	Median								0.0149	0.0155
Gain calibration uncertainty ^b	All sky	0.82 %	0.55 %	0.62%	0.5 %	0.5 %	0.5 %	1.2 %	10 %	10 %
Zero level ^{c} [MJy sr ⁻¹]	All sky	0	0	0	0.0047	0.0136	0.0384	0.0885	0.1065	0.1470
Zero level uncertainty $[\mu K_{CMB}]$	All sky	± 2.23	±0.78	±0.64						
$[MJy sr^{-1}]$	All sky				± 0.0008	± 0.001	± 0.0024	±0.0067	±0.0165	±0.0147
Color correction unc. ^{d}	non-CMB emission	0.1 <i>β</i> %	0.3 <i>β</i> %	0.2 <i>β</i> %	$0.11\Delta \alpha \%$	0.031Δ <i>α</i> %	$0.007\Delta \alpha \%$	$0.006\Delta \alpha \%$	$0.020\Delta \alpha \%$	$0.048\Delta \alpha \%$
Beam Color correction unc. ^{e}	non-CMB emission	0.5%	0.1%	0.3%	<0.3 %	<0.3 %	<0.3 %	<0.5 %	<2.0%	<1.0%



CMB products





European Space Agency







In-flight performance



6000 Prediction 2005 5000 At power spectrum (Bluebook) $((l+1)C_{V}/2\pi \ (\mu K^{2}))$ 4000 level: 3000 2000 1000 0 500 1000 1500 2000 2500 Angular scale 90° 18° 1° 0.2° 0.1° 0.07° 6000 2013 measurements Images speak louder 5000 than words... $\mathcal{D}_{\ell}[\mu K^2]$ 2000 1000 esa 0 1500 500 1000 2 10 50 2000 2500 Multipole moment, ℓ

Astrophysical products





European Space Agency





Please visit <u>www.rssd.esa.int/Planck</u> for all information on Planck

All the Planck products may be downloaded from

http://www.sciops.esa.int/index.php?project=planck&page=Planck_Leg acy_Archive

All the Planck papers may be downloaded from

http://www.sciops.esa.int/index.php?project=PLANCK&page=Planck_Pu blished_Papers

A desk at this symposium will help you access the Planck products







- From a technical point of view, Planck has been a huge success: it has worked without interruption for over twice the intended period, and has met all performance requirements
- 2. With the 2013 release of data and papers, Planck has already fulfilled many of its scientific objectives
- Planck is not finished: next year another data bonanza will be delivered – with significant progress in temperature and a whole new world in polarization !

ENJOY THE SYMPOSIUM !



The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada



Practical informations



- 1. Please deliver your presentation to the drop-off desk, no later than half-day before it is due to be presented !
- 2. We are also collecting poster pdfs... please bring to the drop-off desk
- If you have said you will attend the public session and/or the dinner, but change your mind, please inform the conf desk (as places are limited)
- 4. Note change of programme





Tuesday, 2 April 2013 Session 1: Introduction to Planck and its Products

Room: Newton 1 (Plenary) Chairs: Texier, D.; Lilje, P.



- 09:00 ESA Introduction, *Giménez Cañete, A., Director of Science and Robotic Exploration*
- 09:05 ESA Introduction, *McCaughrean*, *M*.
- 09:15 LFI Introduction, *Mandolesi*, *N*.
- 09:20 HFI Introduction, *Puget,J.L.*
- 09:25 The Planck Mission, *Tauber, J. A.*
- 09:55 Overview of LFI & HFI Frequency Map Generation and their Characteristics, *Zacchei, A.*
- 10:25 Component Separation, Ashdown, M.
- 10:45 Planck non-CMB Component Separation, *Baccigalupi, C*.
- 11:05 Coffee Break, available in Foyer (exit left) and Einstein (exit right)
- 11:40 Consistency of Planck Data, *Lawrence, C. R.*
- 12:00 Planck polarization at small angular scales, *Tristram, M.*
- 12:20 CMB polarization from Planck: status, consistency and prospects, *Natoli, P*.
- 12:40 The Planck Likelihood & power spectrum estimation, *Prunet, S*.
- 13:00 Lunch