Planck early results

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Planck → Third generation of CMB space missions
Primary goals → Measure **CMB temperature anisotropies** to fundamental limits down to 4 arcmin & Measure **CMB polarisation**

- Need to separate CMB from foreground emissions
- Must measure the sky over many frequencies → **A lot of astrophysics and ancillary science** (subject of Planck early results)

- Intensity measured with HFI & LFI at 9 frequencies, 30 to 857GHz
- Polarisation measurements at 7 frequencies, 30 to 353GHz
Planck required sensitivity → Technological performances never achieved in space before.

In particular, flying:

- **Sensitive and fast bolometers** → Need cooling at 100mK
- **Complex cryogenic cooling chain:** 50K (passive) + 20K + 4K + 1.6K + 0.1K (active)
- **100mK** → Obtained from dilution cooler
Planck & Herschel launched on May 14th 2009 (Kourou, Fr. Guyana)

1.5 million km in 45 days → L2 July 2nd 2009

Planck is very stable scanning the sky since August 13th 2009 (~6 month to cover the whole sky)

Nominal mission achieved November 27th 2010

Extended “cryogenic mission” ~Dec. 2011 (5 vs 2 surveys → 30 vs 14 months)
Planck all-sky frequency maps: Foreground maps

Planck early results obtained from data acquired until June 7\textsuperscript{th} 2010
\(~10\) months = complete coverage of sky by all detectors & 60\% overlap between 2 surveys
The Early Release Compact Source Catalogue

- Planck first data product delivered
- First simultaneous radio through sub-mm all-sky survey
- **First all-sky catalogue 100 to 900GHz**

>15000 sources: 9 frequency lists + 2 multi-channel lists (Cold cores & SZ clusters)

Available from ESA Planck legacy archive: www.rssd.esa.int/Planck

- Most radio sources have flat spectra (radio galaxies and NOT IR galaxies detected < 217GHz)
- Radio-source model over-predicts bright counts by factor 2
- Fluctuations (>217GHz) dominated by IR sources

- IR-luminous galaxies
- Radio galaxies, Blazars
- Features in the interstellar medium (flag extended)
- Cold cores/clumps
Cosmic Infra-red Background (CIB)

- **Cumulative IR emission** of dusty star-forming galaxies (IR/Sub-mm emission from UV light reprocessed by dust)
- Probes much of the cosmic star formation
- Longer wavelengths probe higher z → CIB anisotropies in Planck → Forming galaxies @z~2-3

CIB measured by Planck in 6 high galactic latitude fields (total ~40 sq. deg.) with very low dust. Cleaning with template removal:
- CMB → Planck- HFI 143GHz Wiener filtered
- Dust → HI data from GBT *(Martin et al. 2011)*, tracer of diffuse dust emission

*Details in arXiv1101.2028*

- Sub-degree ( l~200 to 1000) structure at all freq. partially correlated across freq. dominates white noise term
- Agrees with other measurements (e.g. BLAST, SPT)
- Constant linear bias model ruled out
The Sunyaev-Zel'dovich (SZ) effect

Inverse Compton interaction in clusters = \textbf{Thermal SZ} another view of the hot intra-cluster gas through the thermal pressure

Doppler effect in clusters = \textbf{Kinetic SZ} very small but may be detected in a statistical way

Galaxy cluster = galaxies + hot gas

Planck observations of A2319 from 44 to 554 GHz
Planck's uniqueness for SZ detection

- Frequency range from 30 to 857 GHz
- All-sky survey

Adapted extraction technique → MMF
Matched Multi-Filter (Melin et al. 2006)
enhances SZ signal over other components
(from red to blue points):
- known spectral dependence → non-relativistic
- known cluster shape → GNFW pressure profile
The ESZ sample
The all-sky Early SZ (ESZ) cluster sample

199 clusters in total including 30 new clusters

ESZ sample = 189 candidates (S/N>6 & |b|>14deg)
- 169 identified with known clusters
- 20 candidates 19 confirmed as new clusters

Further 10 new clusters (S/N<6)

- First & largest all-sky SZ sample of clusters
- Only all-sky cluster survey since ROSAT 1992
- First SZ measure for ~80% of the known clusters
- Moderate redshifts (86% with z<0.3)
- Rarest & most massive clusters over the whole sky (up to $1.5 \times 10^{15}$ $M_\odot$) detected blindly by Planck
- Completes RASS clusters in high M-z region
Planck clusters properties from XMM-Newton

- 21 candidates confirmed with XMM-Newton DDT snapshots
- Most Planck new clusters have **disturbed morphologies**
- **Multiple systems** (double, triple systems) → first super-clusters in SZ

\[ z_{\text{opt}} \sim 0.45, \quad z_\chi \sim 0.45 \]
\[ kT \sim 3\text{keV} \]

Density profiles of Planck new clusters shallower than X-ray clusters of similar masses → X-ray under-luminous for their masses

(Details in arXiv:1101.2025)
Planck's preview of the cluster properties: SZ, optical, X-rays

**SZ signal measured in Planck at cluster positions & binned**

(Details in arXiv1101.2027, 1101.2043)

- **X-rays:** Statistical analysis of ~1600 X-ray clusters, mostly from RASS with homogeneised data (Piffaretti et al. 2010)

- **Optical:** Statistical of ~13000 MaxBCG clusters from SDSS with optical richness (Koester et al. 2007)

**SZ signal $Y_{sz}$ predicted from X-ray and optical relations**

- $Y_{sz}$ from X-rays $\rightarrow$ gas pressure profile (Arnaud et al. 2010) + scaling relations

- $Y_{sz}$ from weak-lensing $\rightarrow$ calibrated $N_{200}$-$M_{500}$ relation (Johnston et al. 2007, Rozo et al. 2009) + gas pressure profile & scaling relations

Minimise systematics $\rightarrow$ consistent approach for (i) SZ extraction & X-ray predictions and (ii) for homogeneisation
Planck's preview of the cluster properties: SZ, X-rays

- SZ measure from Planck & X-ray luminosities (MCXC) agree from highest to lowest luminosity bins
- Excellent agreement with X-ray predictions (normalisation and slope of Y-L and Y-M relations)
- No SZ deficit (Details in arXiv1101.2043)

⇒ Robust and consist overall view of Intra-Cluster Medium properties from X-ray and SZ
Planck's preview of the SZ-optical cluster properties

- SZ detection down to \( \sim 5 \times 10^{13} M_{\text{sol}} \)
- Predictions from combines WL calibration and X-ray model not in agreement with measured SZ signal
- Better agreement for X-ray subsample from SDSS

Unexplained SZ-optical discrepancy between data and prediction:
Sub-population of clusters and Selection effects?
Difference in hydrostatic X-ray and lensing masses?
Dispersion in scaling relations?
A combination of all?
→ Ongoing work...

Details in arXiv1101.2027
Planck prospects for cosmology

- Planck observes on a routine mode since August 13th 2009. Extended “cryogenic-mission” ~December 2011 → 30 months (vs 14) = 5 surveys (vs 2)
- Planck-HFI twice better than requirements (2/3 better @ end extension ~0.33 μK.deg)
- Release of Planck data and cosmological results ~end 2012

Goal → Test simplest inflation: $n_s$ to $4.5 \times 10^{-3}$, $dn_s d\ln k$ to $5. \times 10^{-3}$ (and $\tau$ to $6. \times 10^{-3}$) & non-Gaussianity

Predictions of power spectra measurements from the Blue book (nominal 14month mission)
Planck prospects for cosmology

Goal → **Constrain the tensor to scalar ratio from B-modes**
Test case from simulation template fitting using Planck channels 30 and 217 (353) GHz

→ Planck should detect tensor-to-scalar ratio down to 0.05
Blue: nominal mission
Magenta: extended mission

*Efstathiou & Gratton 2009*
"Legacy" from Planck early results

**Noise Level OK** → Sensitivity (~0.5 μK.deg) twice better than requirements (WMAP ~5.3 μK.deg in 8yrs) extended mission ~0.33 μK.deg
→ 10 sigma detection of CIB (0.1% CMB) @l=200

**Challenges for cosmology**
→ Control of instrumental systematics (intensity and polarisation)
→ Control of astrophysical contamination for intensity (high l) & polarisation (E and B modes)

I. **For Polarisation**: Two main polarised foregrounds
- Synchrotron emission (40%) → measured @30GHz
- Interstellar dust (5%) → measured @353GHz

II. **For Intensity**: Main domains of progress for component separation
- Anomalous emission measured by Planck & fitted all over the sky
- Dust model improved (evolution from diffuse ISM to molecular clouds, emission from diffuse molecular hydrogen, CO emission)
“Legacy” from Planck early results

II. For Intensity: Main domains of progress for cosmological parameter estimates

- CIB anisotropies measured (high l control)
- Radio counts & model improved (high l control)
- Model of SZ signal improved from converging view of the ICM (high l control)
- Future constraints from clusters (ESZ ~4 times larger than present SZ samples, Most complete set of the most massive clusters at z<0.5)
- Lensing measurements
- And more

Planck is a CMB mission with very wide astrophysical capabilities (19 Planck early result articles, 10months of data ~6 months of analysis)

- Limited resolution (>4') but excellent sensitivity
- All-sky survey, First ever above 100GHz
More to come in the future