The Planck Early Release Compact Source Catalog

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on behalf of the Planck Collaboration
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R. Chary: Paris, Jan 2011
The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 50 scientific institutes in Europe, the USA and Canada.

Planck is a project of the European Space Agency -- ESA -- with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.
ERCSC Requirements

- **Early Release: Start of Science Operations (Aug 2009) + 16 months**
- **Data from first Planck sky survey**
  - Actually using 1.6 sky coverages; By Jan 2012 ~4.5 sky coverages
  - ERCSC uses all data between Aug 2009 and June 2010
- **To enable follow up in a timely manner with Herschel**
  - Deadline for Herschel proposals ~ mid-2011
- **High reliability sources**
  - >90% reliability all sky
  - 30% accuracy photometry, corresponds to a 5sigma catalog
  - FWHM/5 astrometry
- Include two additional catalogs based on multifrequency analysis
  - cold (Far-infrared color temperature T<14K) prestellar cores (ECC)
  - Galaxy clusters detected through the Sunyaev Zeldovich effect (ESZ)
- **No completeness requirement and no polarization information**
  - Could be missing a 100 Jy source if it were hidden behind a planet
- **No bandmerging requirement; but bandfilled for 857 GHz sources**
  - Bandmerging is challenging due to range in spatial resolution

R. Chary: Paris, Jan 2011
Step 1
- Take all-sky Intensity and Covariance Maps from 1.6 sky surveys, convert to $K_{RJ}$

Step 2
- Run 4 source detection codes on maps
- Generate RMS noise map using a 2deg moving annulus from source subtracted map

Monte-Carlo Analysis
- Inject artificial point sources into maps
- Rerun 4 detection codes
- Study extracted properties of artificial sources after excluding “real” sources from Step 2

Cut 1
- Apply SNR cut (FLUX/RMS noise) so ERCSC requirements are met on artificial sources
  - Flux density uncertainty <30% and position accuracy < FWHM/5
  - Apply same SNR cut per frequency to real sources (SNR varies with freq.)

Cut 2
- Reject spurious sources such as hot pixels, instrumental artifacts, planet sidelobes
- Select 2 algorithms which have the largest # of sources in the >90% reliability cat.
  - PowellSnakes (30-143 GHz; P. Carvalho et al. 2009) and Sextractor (217-857 GHz; Bertin & Arnouts 1996)

Validation
- Use external catalogs such as QSOs, WMAP, VLA
- Use predictive flux catalog from pre-selected bright sources
- Compare catalogs from jacknife tests which include only half the data
The Planck one-year all-sky survey

(c) ESA, HFI and LFI consortia, July 2010
Features of Planck

- **Unique phase space** – the first simultaneous radio through submillimeter all sky survey
  - Fills in the gap in phase space between WMAP and Akari/IRAS
  - Probes both the dusty infrared luminous sources and the radio/synchrotron sources
- Spatial resolution well matched to IRAS at \( \times 3 \) longer wavelengths
- Improved spatial resolution and sensitivity compared to WMAP in the radio

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- Fills in the gap in phase space between WMAP and Akari/IRAS
- Probes both the dusty infrared luminous sources and the radio/synchrotron sources
- Spatial resolution well matched to IRAS at \( \times 3 \) longer wavelengths
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ERCSC Sensitivity

Planck Galactic Plane
|b|<10 deg

Planck Extragalactic
|b|>30 deg

References
C. Beichman et al. 1988
B. Gold et al. 2010
P. Gregory et al. 1996
T. Murphy et al. 2010
E. Wright et al. 2009
But coverage is not uniform

- Ecliptic Plane has fewer observations than Ecliptic Poles due to scan strategy
- Galactic ISM emission also reduces sensitivity to compact sources close to the Galactic Plane.
Planck Early Release Compact Source Catalog

PER030 (30 GHz)
ILC model of CMB subtracted
Catalog: ERCSC_f030.fits (706 sources) sorted by GLON
Origin: U.S. Planck Data Center
Date: 2010-09-04
Map: /atilc/ercsc/RUNS/p4.0_ILC/MAPS/LLF_030.fits
Image width: 2.20 deg

Has Galactic, Equatorial coordinates, flux density and E for extended

R. Chary: Paris, Jan 2011
Planck Early Release Compact Source Catalog

PER857 (857 GHz)

ILC model of CMB subtracted

Catalog: ERCSC_f857.fits (9042 sources) sorted by GLON

Origin: U.S. Planck Data Center

Date: 2010-09-04

Map: /attic/ercsc/RUNS/p4.0_ILC/MAPS/HFI_857.fits

Image width: 0.33 deg
Planck Sources Seen by WMAP

- ERCSC at 030 GHz: 489
- Matched WMAP 5σ sources at 033 GHz: 253

- ERCSC at 044 GHz: 221
- Matched WMAP 5σ sources at 041 GHz: 175

- ERCSC at 070 GHz: 246
- Matched WMAP 5σ sources at 061 GHz: 135

- ERCSC at 100 GHz: 531
- Matched WMAP 5σ sources at 094 GHz: 56
Positional Validation using QSOs

- 30 <2'
- 70 <1'
- 143 <0.5'
- 44 <2'
- 100 <0.75'
- 217 <18"

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70 GHz Planck flux density is lower than a simple VLA 22-43 GHz extrapolation

- Likely reason is change in spectral index at >44 GHz
- See Planck Collaboration 2011j for details
Flux Density Validation using Predictive Flux Catalog

ARP220

\[ \chi^2 = 1.6 \]

Cygnus A

\[ \chi^2 = 0.3 \]

MESSIER001

\[ \chi^2 = 1.1 \]

NGC0157

\[ \chi^2 = 2.4 \]

Black: Archival data
Blue: Prediction
Red: Planck ERCSC

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Spectral Index of ERCSC Sources: Need two flux density points

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<tr>
<th>Frequency</th>
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<th>B</th>
<th>C</th>
<th>D</th>
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\(F\) Fraction of sources detected either at frequency just below or just above given frequency
Interesting selection effect at both 30 GHz & 857 GHz

$S \propto \nu^\alpha$
Beam dilution at lowest Planck frequencies (=<70 GHz) reduces SNR of detections
So ESZ is based on a blind run at HFI frequencies

Carlstrom et al. 2002, ARA&A
ESZ Characteristics

- ~1000 candidates in blind search
- Culled to 189 robust objects
- $z<0.6$
- Large fraction are X-ray confirmed
- First detection of SZ effect in majority of ROSAT clusters
- See Planck Collaboration 2011d & e
- Science results 2011d-h
Early Cold Core (ECC) catalog

- A warm template from the IRAS 100 micron map is subtracted from each of the 353, 545 and 857 GHz images and a source detection run on each band.
- The single frequency sources are merged together using a matching threshold of 5’
- The S/N>4 in each band
- A modified black body is fit to the multiband photometry
- Only SNR>15 sources are found to have robust fit parameters from the MC: 915 sources with T<14K

See Planck Collaboration 2011r & s Science results in 2011q-u
Contents of ERCSC

Catalogs from Intensity Maps

- ERCSC_f030.fits
- ERCSC_f044.fits
- ERCSC_f070.fits
- ERCSC_f100.fits
- ERCSC_f143.fits
- ERCSC_f217.fits
- ERCSC_f353.fits
- ERCSC_f545.fits
- ERCSC_f857.fits with bandfilled info at 217, 353 and 545 GHz

- *fluxmap.pdf: Sky distribution with flux information
- ERCSC cutouts from CMB subtracted maps: 4*FWHM on a side
- PSF cutouts for each source: 4*FWHM on a side

| All sky | |b|>30 |
|---------|---------|
| 705     | 307     |
| 452     | 143     |
| 599     | 157     |
| 1381    | 332     |
| 1764    | 420     |
| 5470    | 691     |
| 6984    | 1123    |
| 7223    | 2535    |
| 8988    | 4513    |

- ECC.fits (915 entries; 35 at |b|>30)
- Planck_ECC.pdf: ECC cutouts on 353, 545 and 857 residual maps; 0.33 deg on a side
- ECC_skymap.pdf: Sky distribution of ECC candidates

- ESZ.fits  (189 sources; 134 at |b|>30)
- ESZ_skymap.pdf: Sky distribution of ESZ candidates

- Explanatory Supplement
Value Added Contents

• Dates on which source was observed by Planck
  – For variability analysis with ground-based data
  – ERCSC by itself gives only a single flux density which is the average of all scans through the source

• Planck PSF parameters and PSF fit flux density
  – Leveraging successful development of FEBECOP
  – Flag extended sources

• Detection of source in CMB subtracted maps
  – Provides a safety margin for conservative user

• Explanatory notes on individual sources including IDs in external catalogs and possible information about variability

• Redshift and physical parameters of X-ray detected clusters

• Various cirrus indicators: IRAS 100 micron surface brightness available (MJy/sr) through archive interface, CIRRUS (0-1) and EXTENDED flag (0/1)
Summary

• The Early Release Compact Source Catalog (ERCSC) is an early, >90% reliability catalog based on 1.6 sky coverages
• Produced and released with a rapid turnaround (<9 months)
• Consists of 9 single frequency catalogs as well as bandfilled 217-857 GHz entries for each 857 GHz source
• Includes the Early Cold Cores (ECC) and Early SZ-cluster (ESZ) catalogs
• More than 15000 unique sources including stars with dust shells, cold molecular cloud cores, radio galaxies, blazars, infrared luminous galaxies, Galactic ISM features, SZ clusters
  - Beware of CO contamination for Galactic sources at 100 GHz
• Available from ESA Planck Legacy Archive and NASA’s Infrared Science Archive (IRSA) starting Jan 11, 2011
• Interesting astrophysics is evident in the ERCSC and is discussed in this conference
• Ripe for follow-up with Herschel, SOFIA, ALMA, VLA etc.
Evidence for cold dust in galaxies: Implications for SMGs

A 2mJy SMG would be a x2 less luminous (and thereby less SFR) at almost all redshifts

Evidence for more cold dust in nearby galaxies

R. Chary: Paris, Jan 2011