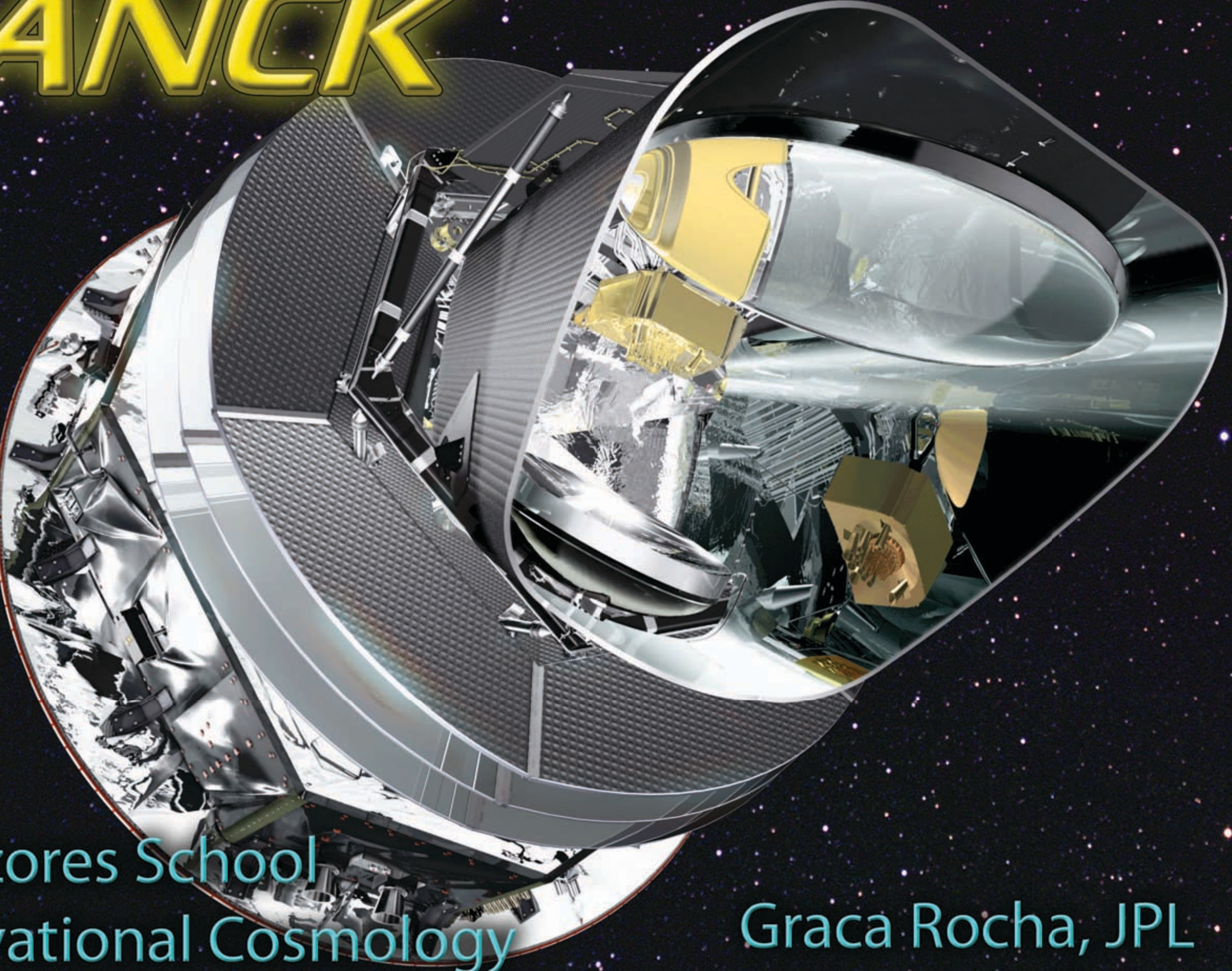
Early Astrophysics Results from PLANCK



Azores School
on Observational Cosmology
Sept. 2011

Graca Rocha, JPL
for the Planck Collaboration

Planck

- Planck's primary design goal is to

  MEASURE THE TEMPERATURE ANISOTROPIES OF THE CMB TO FUNDAMENTAL LIMITS DOWN TO 5 ARCMINUTES

  - Also to

    MEASURE THE POLARIZATION OF THE CMB

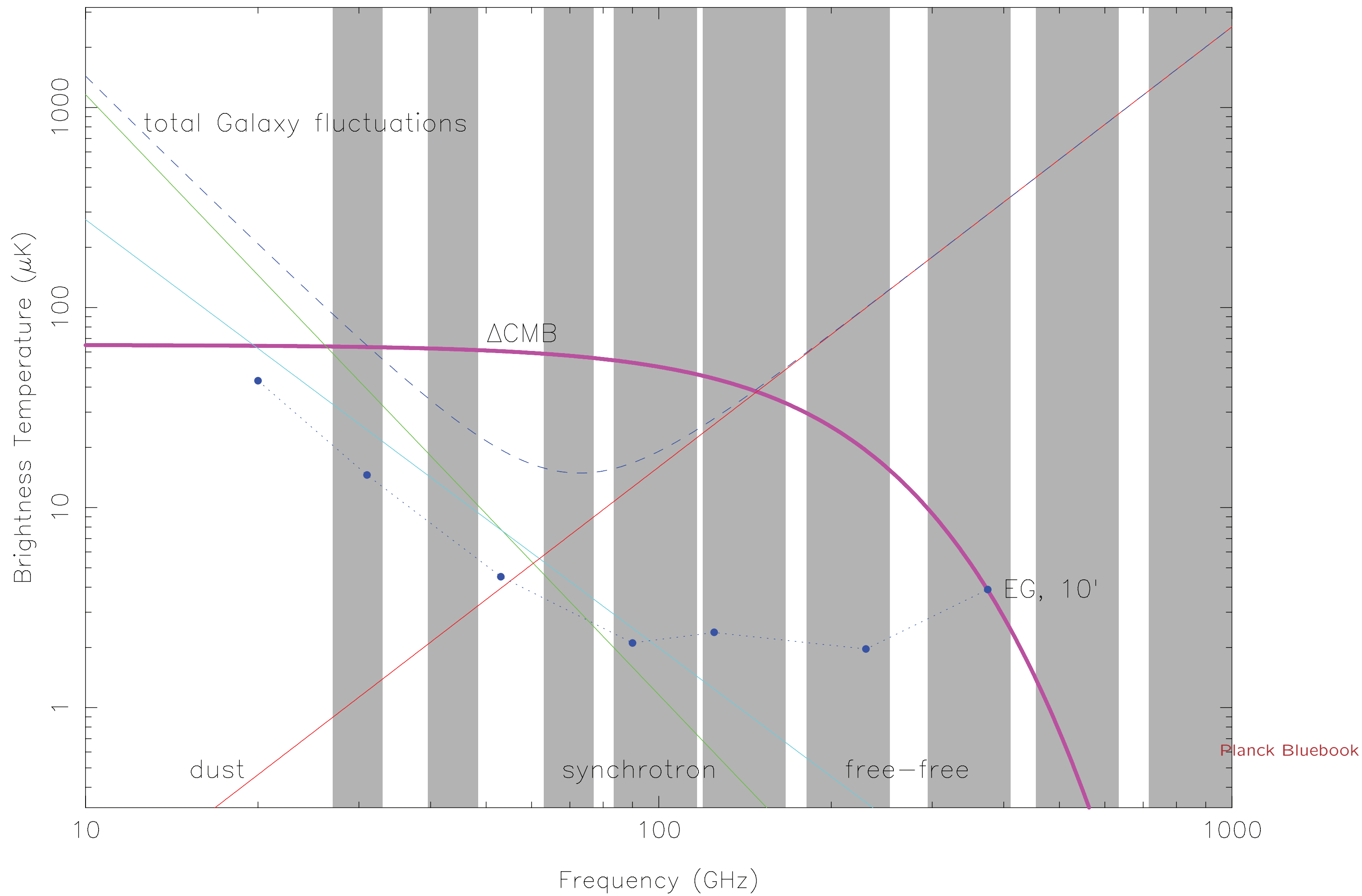
- To do these, we must be able to separate the CMB from foreground radiation

- To do that, we must measure over a wide frequency range

- Of necessity, we measure the foregrounds very well

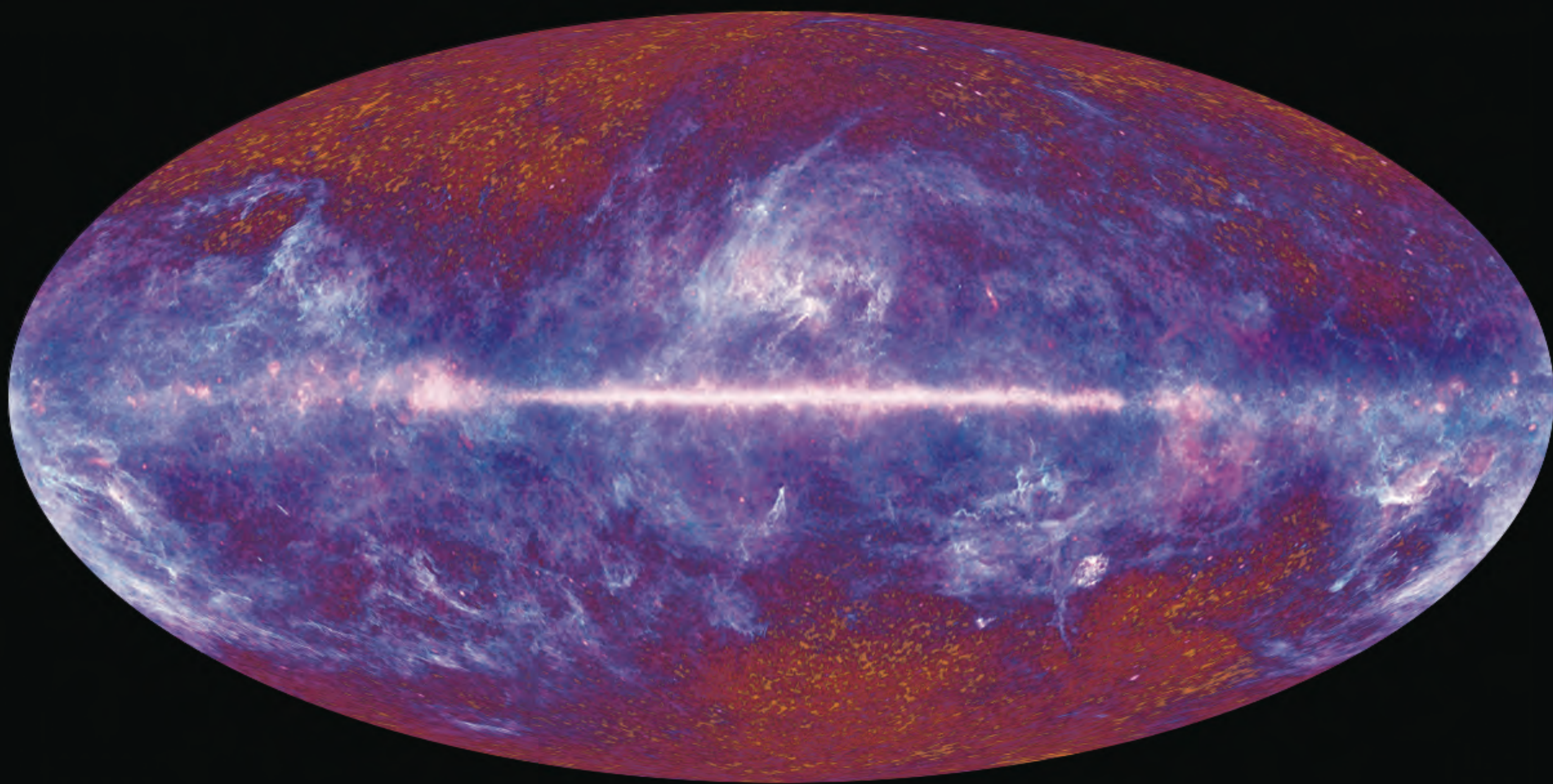
  $\Longrightarrow$ LOTS OF ASTROPHYSICS

Planck Frequencies



- Temperature measurement at nine frequencies: 30, 44, 70, 100, 143, 217, 353, 545, 857 GHz
- Polarization measurements at seven frequencies: 30, 44, 70, 100, 143, 217, 353 GHz

Planck's Universe



The Planck one-year all-sky survey

esa

Today

The Planck Collaboration is releasing:

- The Early Release Compact Source Catalogue (ERCSC)
  - The first data product from Planck
- Seven papers describing the performance of the Planck mission and instruments in space, and the data processing that went into the ERCSC and the science results
  - Mission overview
  - Thermal performance
  - LFI & HFI instrument performance
  - LFI & HFI data processing
  - ERCSC

Today — cont'd

- Eighteen papers reporting early Galactic and extragalactic science results from Planck
  - 5 on Sunyaev-Zeldovich clusters
  - 3 on extragalactic radio sources
  - 1 on the cosmic infrared background
  - 2 on dusty galaxies, including the Magellanic Clouds
  - 5 on dust in the Milky Way, including spinning dust
  - 2 on cold cores or clumps
- All titles begin with "Planck Early Results:"
- Author lists begin with "Planck Collaboration", followed by names in alphabetical order.

Where To Find Things

- ERCSC

  http://www.sciops.esa.int/index.php?project=planck&page=Planck Legacy Archive

  http://irsa.ipac.caltech.edu/Missions/planck.html

- Papers

  http://www.rssd.esa.int/index.php?project=planck

  – Late this afternoon, on astro/ph

- Posters, one per paper, in poster session 243 today, opposite the Planck booth
- A list of papers, with titles and a sequence designator that reflects the posters, at the Planck booth

PLANCK Early Results

planck

List of Early Papers

***Planck* Collaboration**

Papers submitted on Jan 11 2011

Planck identifier	Title (all titles are prefixed with "*Planck* Early Results: ")
2011a	The *Planck* mission
2011b	The thermal performance of *Planck*
2011c	First assessment of the Low Frequency Instrument in-flight performance
2011d	First assessment of the High Frequency Instrument in-flight performance
2011e	The Low Frequency Instrument data processing
2011f	The High Frequency Instrument data processing
2011g	The Early Release Compact Source Catalogue
2011h	The all-sky early Sunyaev-Zeldovich cluster sample
2011i	*XMM-Newton* follow-up for validation of *Planck* cluster candidates
2011j	Statistical analysis of Sunyaev-Zeldovich scaling relations for X-ray galaxy clusters
2011k	Calibration of the local galaxy cluster Sunyaev-Zeldovich scaling relations
2011l	Cluster Sunyaev-Zeldovich optical scaling relations
2011m	Statistical properties of extragalactic radio sources in the *Planck* Early Release Compact Source Catalogue
2011n	Early Release Compact Source Catalogue validation and extreme radio sources
2011o	Spectral energy distributions and radio continuum spectra of northern extragalactic radio sources
2011p	The *Planck* view of nearby galaxies
2011q	Origin of the submillimetre excess dust emission in the Magellanic Clouds
2011r	The power spectrum of cosmic infrared background anisotropies
2011s	All-sky temperature and dust optical depth from *Planck* and *IRAS* — constraints on the "dark gas" in our Galaxy
2011t	New light on anomalous microwave emission from spinning dust grains
2011u	Properties of the interstellar medium in the Galactic plane
2011v	The submillimetre properties of a sample of Galactic cold clumps
2011w	The Galactic cold core population revealed by the first all-sky survey
2011x	Dust in the diffuse interstellar medium and the Galactic halo
2011y	Thermal dust in nearby molecular clouds

Planck on the Web

European Planck website: http://www.rssd.esa.int/index.php?project=Planck
U.S. Planck website: http://planck.ipac.caltech.edu

The Early Release Compact Source Catalogue

- First Planck data product to be released

  http://www.sciops.esa.int/index.php?project=planck&page=Planck Legacy Archive

  http://irsa.ipac.caltech.edu/Missions/planck.html

- Contents:
  - Lists of sources at nine frequencies 30, 44, 70, 100, 143, 217, 353, 545, 857 GHz

    Temperature only, no polarization
  - List of galaxy clusters detected through the Sunyaev-Zeldovich effect
  - List of cold cores detected through their spectral signature

Motivation for the ERCSC

- Provide an early release of data from Planck
- Enable follow-up observations with (especially) Herschel, launched together with Planck and with a limited cryogenic lifetime
  - Second AO for Herschel was anticipated to be 20 months after launch, with proposals due 24 months after launch
- To be delivered by the US Planck Data Center at IPAC to the Planck Data Processing Centers 6 months after completion of the first sky survey.
- Delivered 7 September, six days early(!), based on almost 10 months of observations = 1.6 sky surveys.
- 3-month validation process

Characteristics of the ERCSC

- Frequencies from 30 to 857 GHz — a factor of almost 30
- All-sky
- First ever all-sky survey between 100 and 1000 GHz sensitive enough to detect individual objects
  - 10^4 times as sensitive to compact sources as FIRAS!
- First simultaneous radio-through-submillimeter all-sky survey
- Three different regimes:
  - CMB-limited
  - Noise-limited
  - Confusion-limited
- Plus the Galactic background changes dramatically over the sky
- Early
- Reliable (i.e., sources are real)
  - Goal $> 90\%$ over whole sky, $> 95\%$ at high Galactic latitudes

ERCSC Numbers

- Nine frequency lists:

able 3. *Planck* ERCSC Characteristics

Freq [GHz]	30	44	70	100	143	217	353	545	857
λ [μm]	10000	6818	4286	3000	2098	1382	850	550	350
Sky Coverage in %	99.96	99.98	99.99	99.97	99.82	99.88	99.88	99.80	99.79
Beam FWHM [arcmin][a]	32.65	27.00	13.01	9.94	7.04	4.66	4.41	4.47	4.23
# of Sources	705	452	599	1381	1764	5470	6984	7223	8988
# of $\|b\| > 30°$ Sources	307	143	157	332	420	691	1123	2535	4513
$10\sigma^b$ [mJy]	1173	2286	2250	1061	750	807	1613	2074	2961
$10\sigma^c$ [mJy]	487	1023	673	500	328	280	249	471	813
Flux Density Limit[d] [mJy]	480	585	481	344	206	183	198	381	655

otes. [(a)] The precise beam values are presented in Zacchei et al. (2011) and Planck HFI Core Team (2011b). This table shows the values whi
ere adopted for the ERCSC. [(b)] Flux density of the median $>10\sigma$ source at $|b| > 30°$ in the ERCSC where σ is the photometric uncertainty of t
urce. [(c)] Flux density of the faintest $>10\sigma$ source at $|b| > 30°$ in the ERCSC. [(d)] Faintest source at $|b| > 30°$ in the ERCSC.

- Early SZ (ESZ) list:
  - 189 clusters
- Early Cold Cores (ECC) list:
  - 915 cold cores

ERCSC Methodology — Frequency Lists

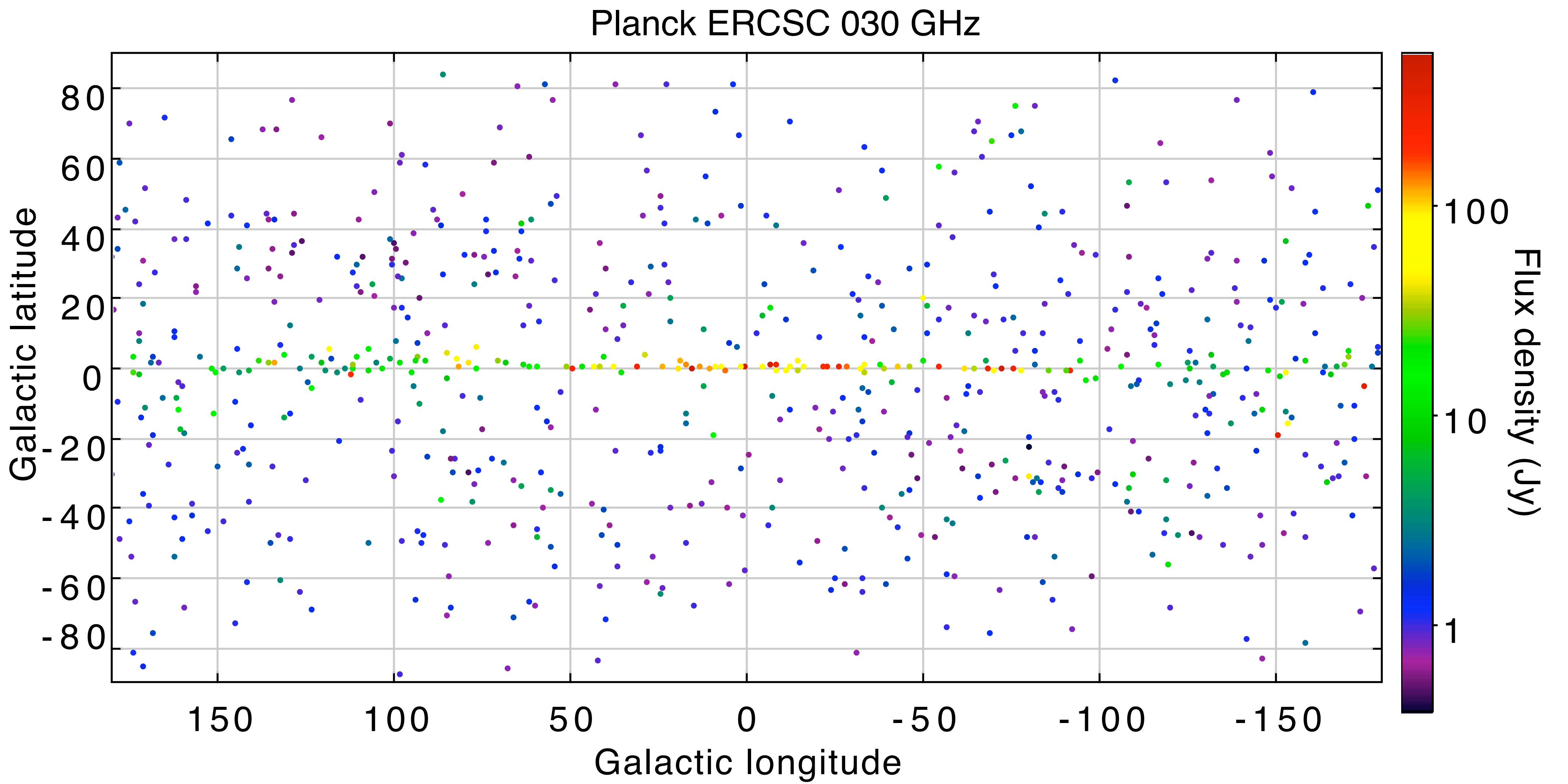
- Source finding algorithms were run independently at each frequency to generate an initial source list
- Simulated sources (typically 1000 per run $\times$ 10 runs) were injected into the data, and the source finding re-run
- Comparison of detected vs. injected simulated sources provided an estimate of the reliability of source finding as a function of flux density and postition on the sky.
  - Called the Monte Carlo Quality Assessment (MCQA)
  - To be considered a match, a detected source had to be within 2 $\times$ FWHM in position and agree within 30% with the injected source flux density
- Reliability is assessed as a function of SNR (flux density/local background rms)
- Sources sorted by SNR, the cumulative reliability calculated as a function of flux density cutoff. Cutoff chosen so that cumulative reliability $>$ 90%.
- Source finding algorithm chosen that maximized number of sources at a given frequency for reliability $>$ 90%.
  - PowellSnakes 30–143 GHz
  - SExtractor 217–857 GHz

ESZ & ECC Methodology

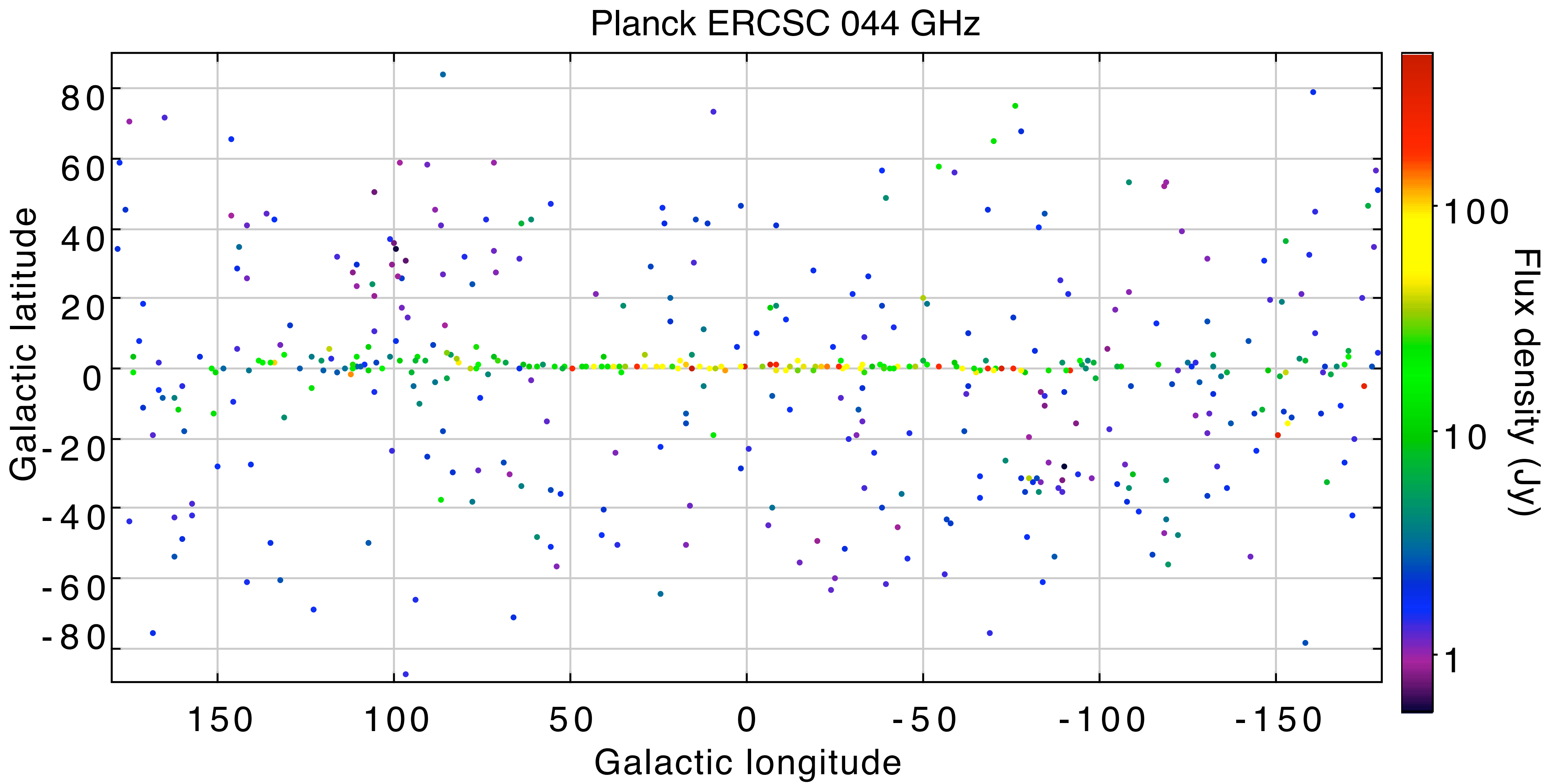
- The spectral characteristics of SZ clusters and cold cores are known
- Using these known characteristics to search simultaneously at multiple frequencies increases the sensitivity of the search for these objects dramatically
- ESZ
  - The matched multi-frequency filter then optimally combines the six frequencies of each patch, assuming the SZ frequency spectrum and using the Arnaud et al. (2010) pressure prole as the cluster profile. Auto- and cross- power spectra used by the MMF are directly estimated from the data. They are thus adapted to the local instrumental noise and astrophysical contamination such as ISM emission. For each patch, the scale radius of the cluster prole is varied to maximise the signal-to-noise ratio of each detection. The algorithm thus assigns to each detected source an estimated size and an integrated ux.
  - Unlike the individual frequency source list or the ECC list, which are validated through a Monte-Carlo technique, the reliability of the ESZ list has been estimated through a validation process based on internal checks and on cross-checks with ancillary optical/near-infrared and X-ray cluster catalogues or images.

ESZ & ECC Methodology — cont'd

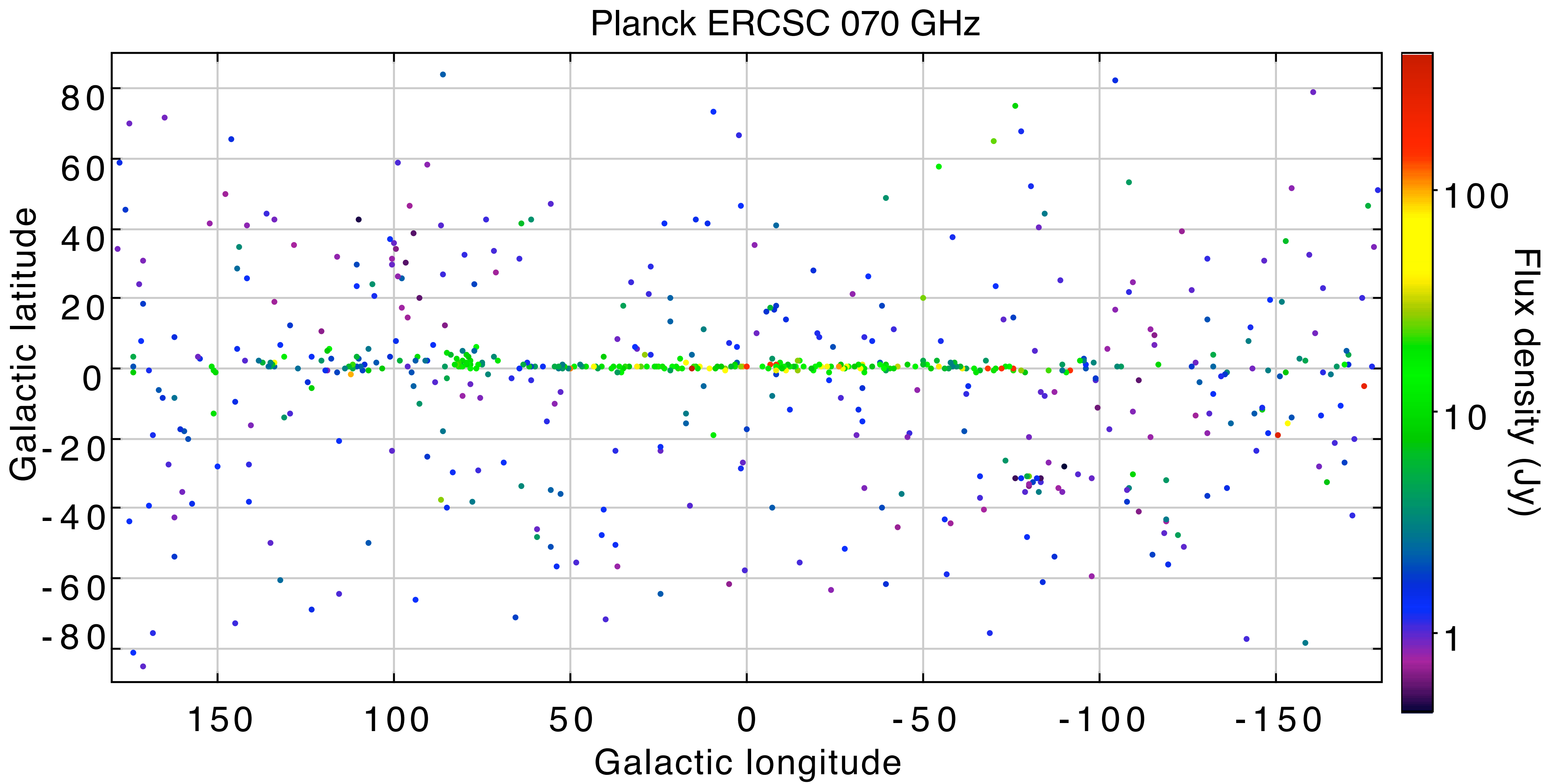
- ECC
  - Subtract warm background estimated from IRAS 100 μm maps and local color
  - Find sources, match objects in the 353 GHz detection list against both the 545 and 857GHz catalogues using a $5'$ matching radius.
  - Sources detected in only one or two bands are discarded.
  - The SNR and position of the detection having the greatest SNR are assigned to the band-merged entry.
  - Aperture photometry on 100 μm, 353, 545, and 857 GHz maps with source radius $5'$ and a background annulus 5–$10'$.
  - Unconstrained three-parameter (T,β, and $S(857)$) greybody is fit to the four-band aperture photometry with the fitted temperatures used in the source selection process.
  - Two criteria applied: SNR > 15
    $T < 14$ K
  - These criteria were chosen based on the Monte Carlo Quality Assessment to ensure reliability $> 90\%$.

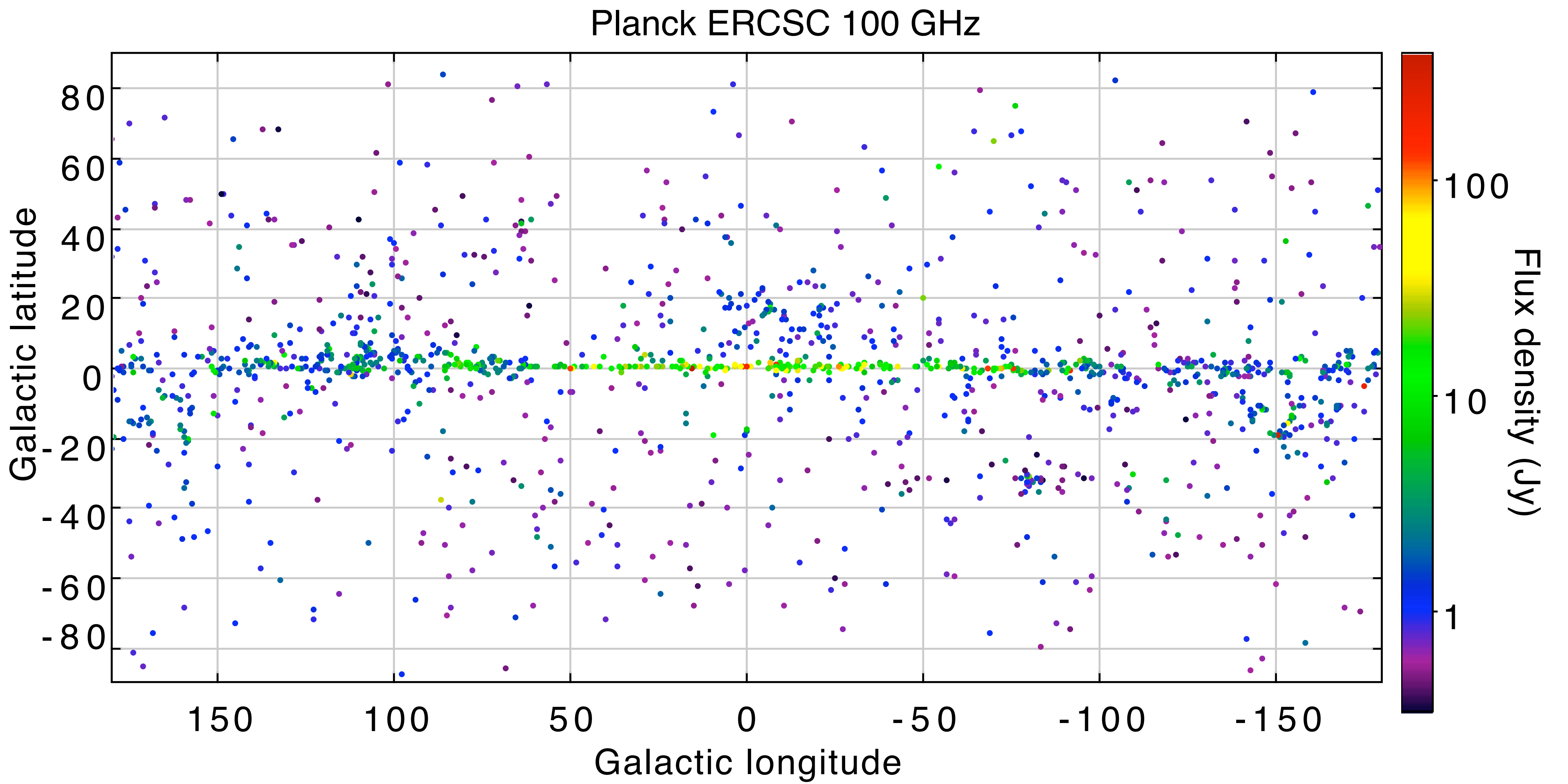


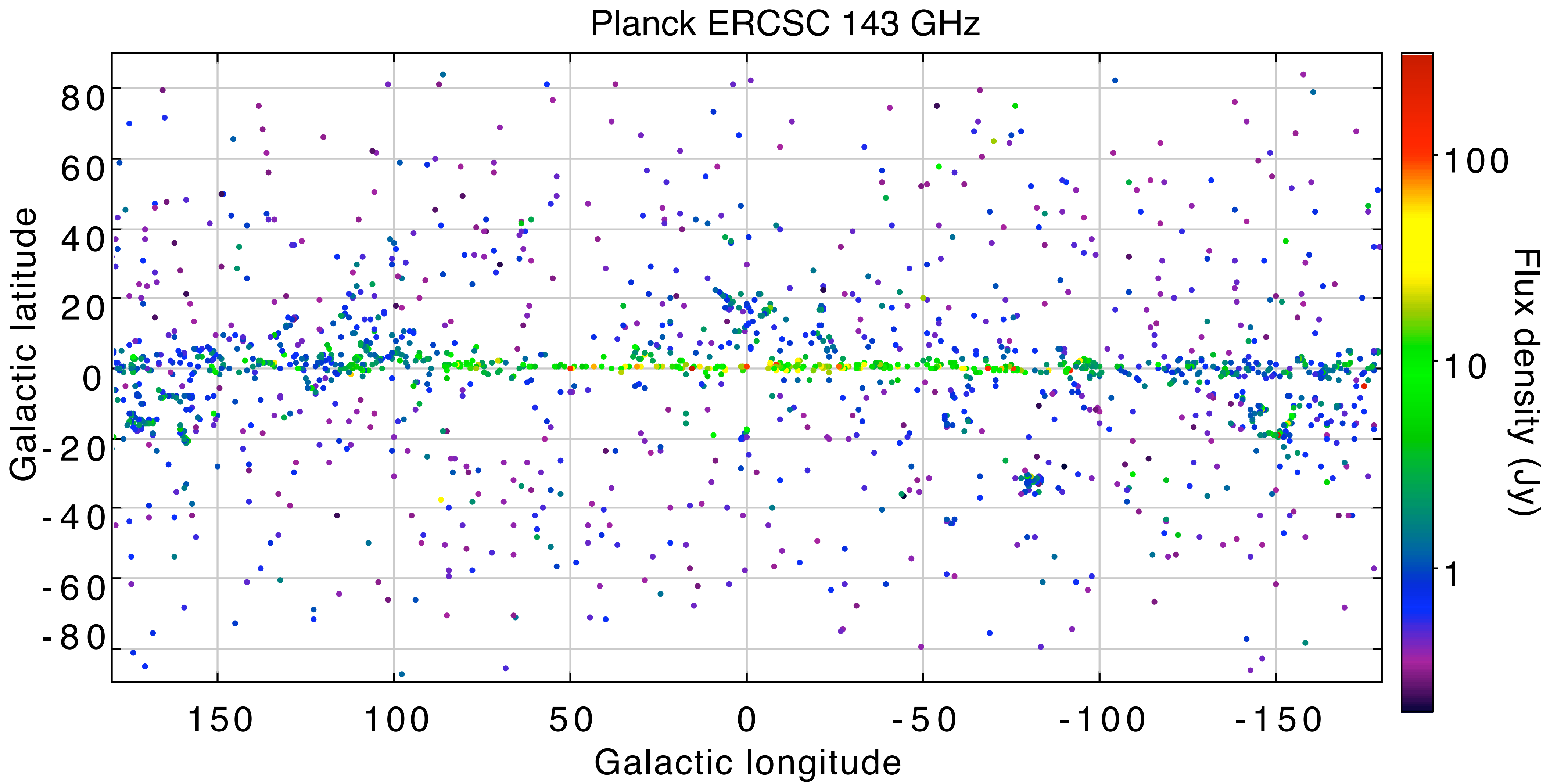
Planck ERCSC 030 GHz
Galactic latitude
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
Galactic longitude
Flux density (Jy)
100
10
1

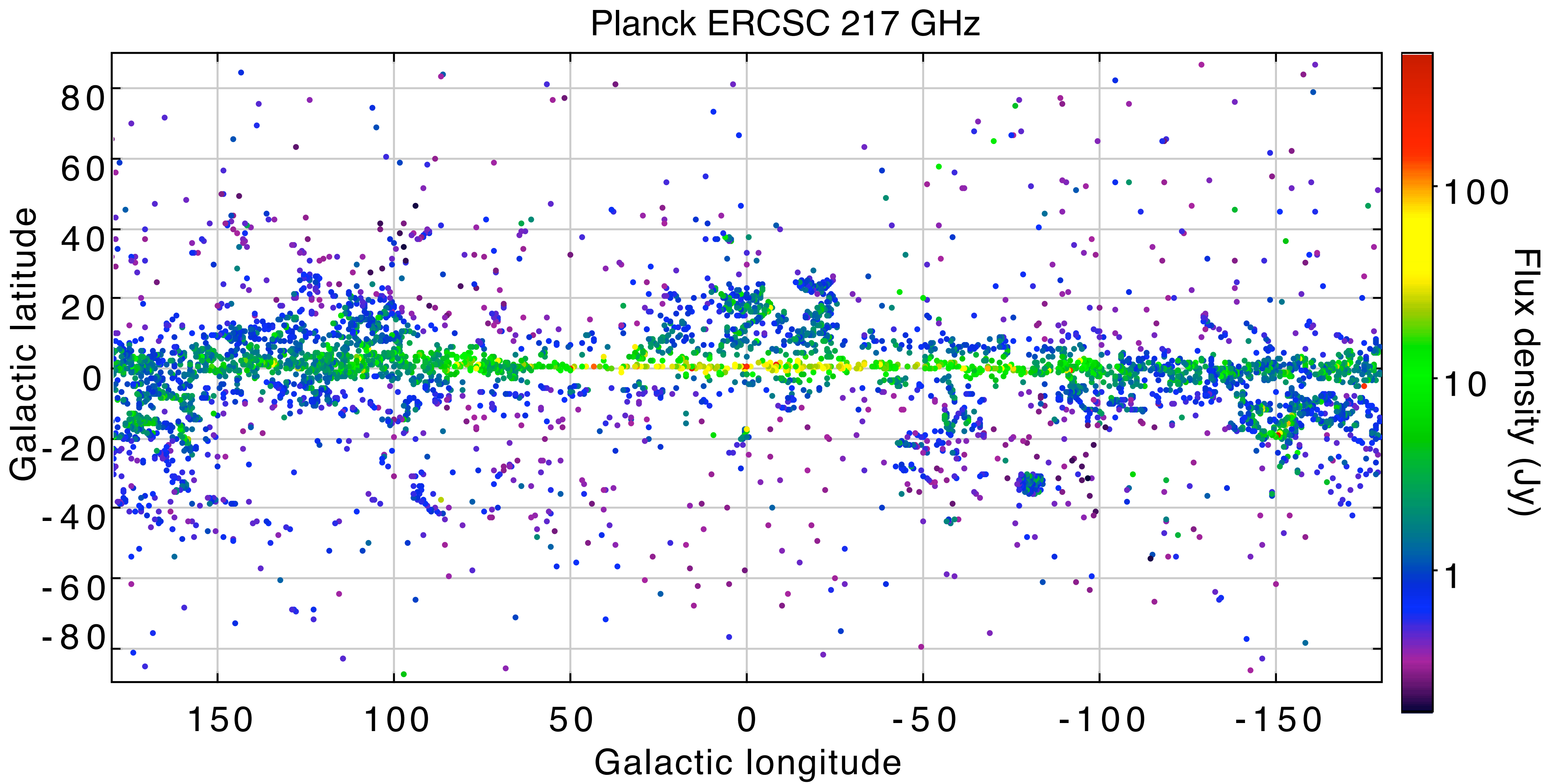


Planck ERCSC 044 GHz
Galactic latitude
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
Galactic longitude
Flux density (Jy)
100
10
1

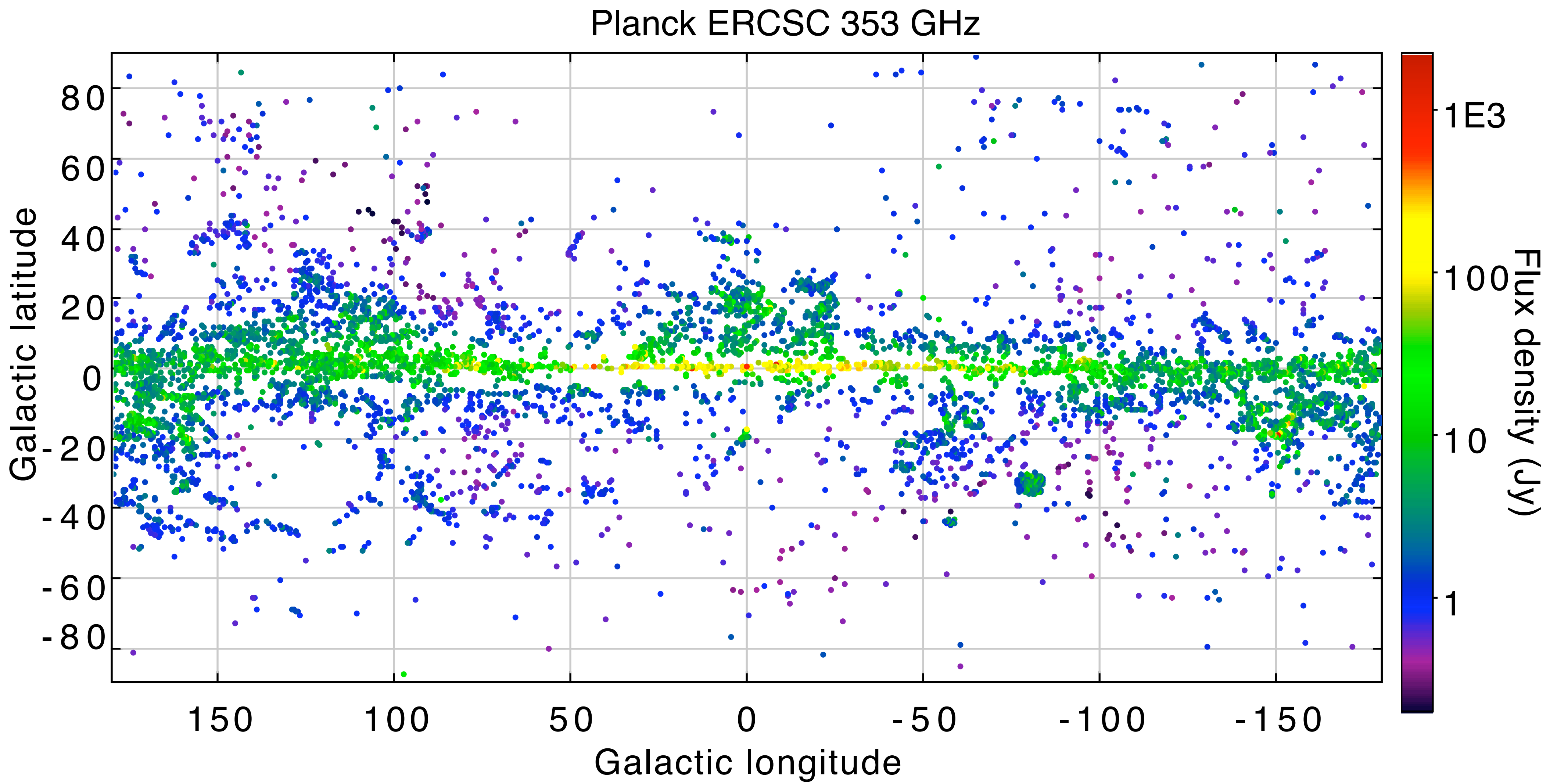

Planck ERCSC 070 GHz
Galactic latitude
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
Galactic longitude
Flux density (Jy)
100
10
1


Planck ERCSC 100 GHz
Galactic latitude
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
Galactic longitude
Flux density (Jy)
100
10
1

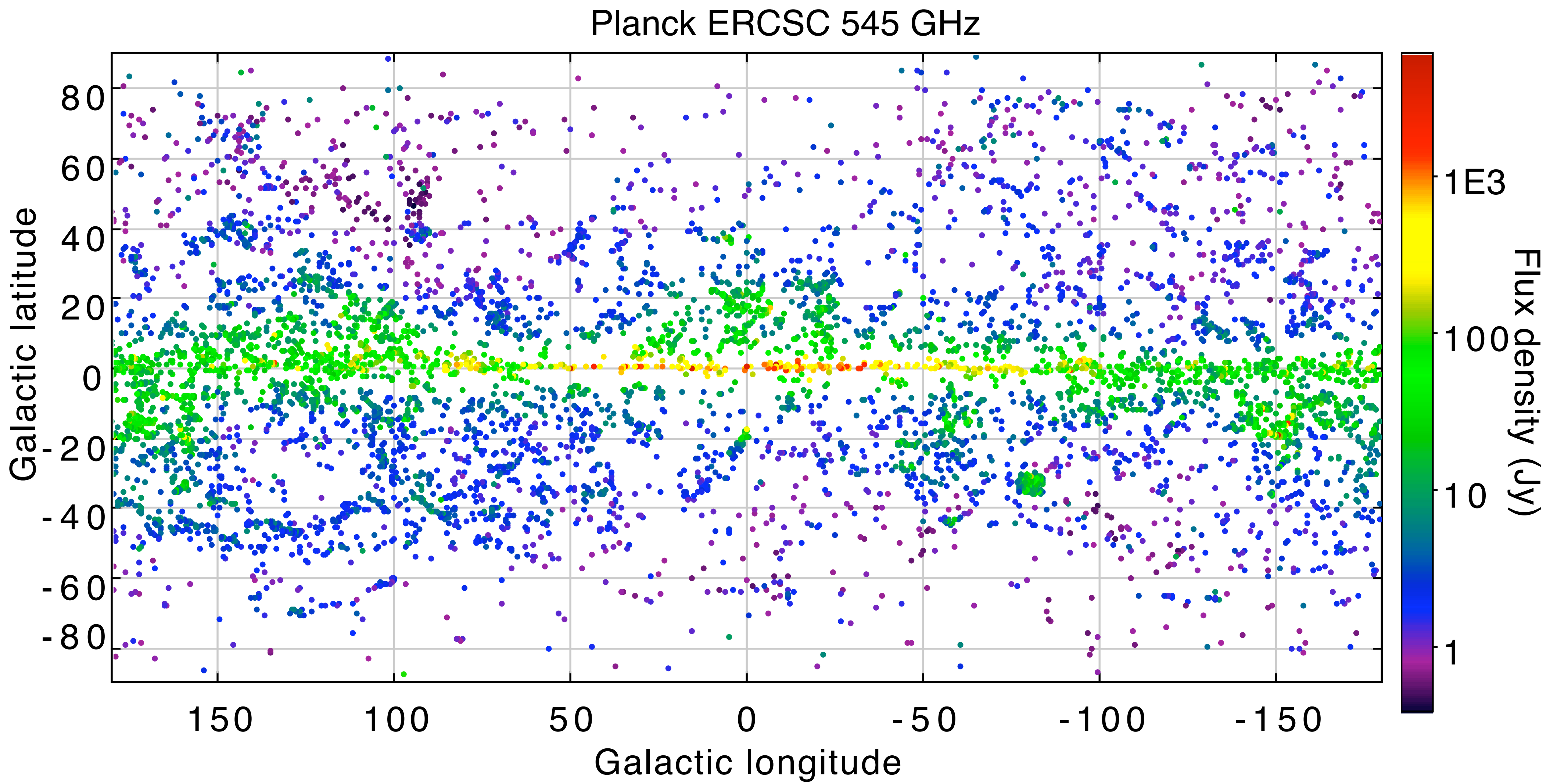

Planck ERCSC 143 GHz
Galactic latitude
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
Galactic longitude
Flux density (Jy)
100
10
1

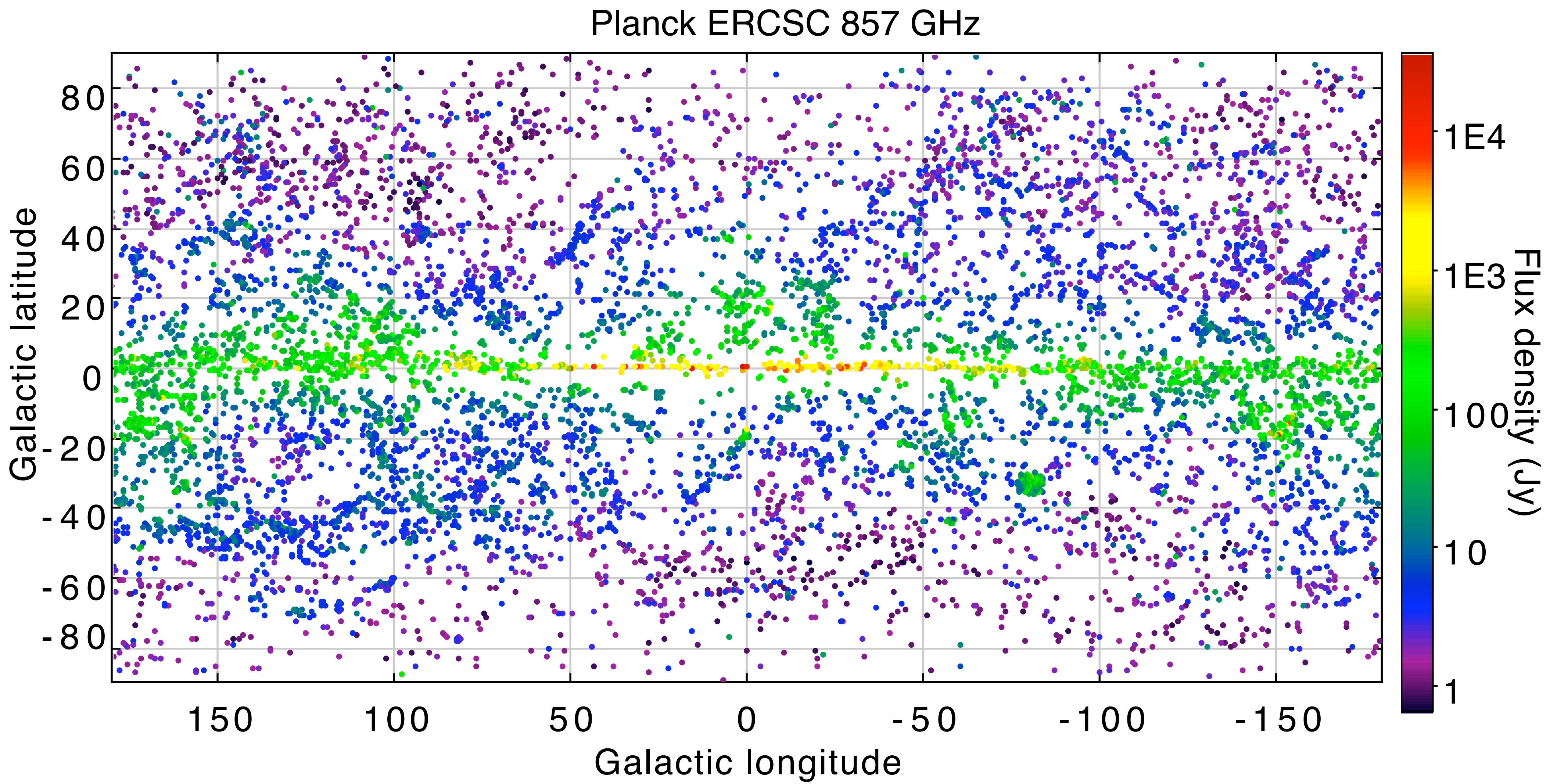


Planck ERCSC 217 GHz
Galactic latitude
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
Galactic longitude
Flux density (Jy)
100
10
1

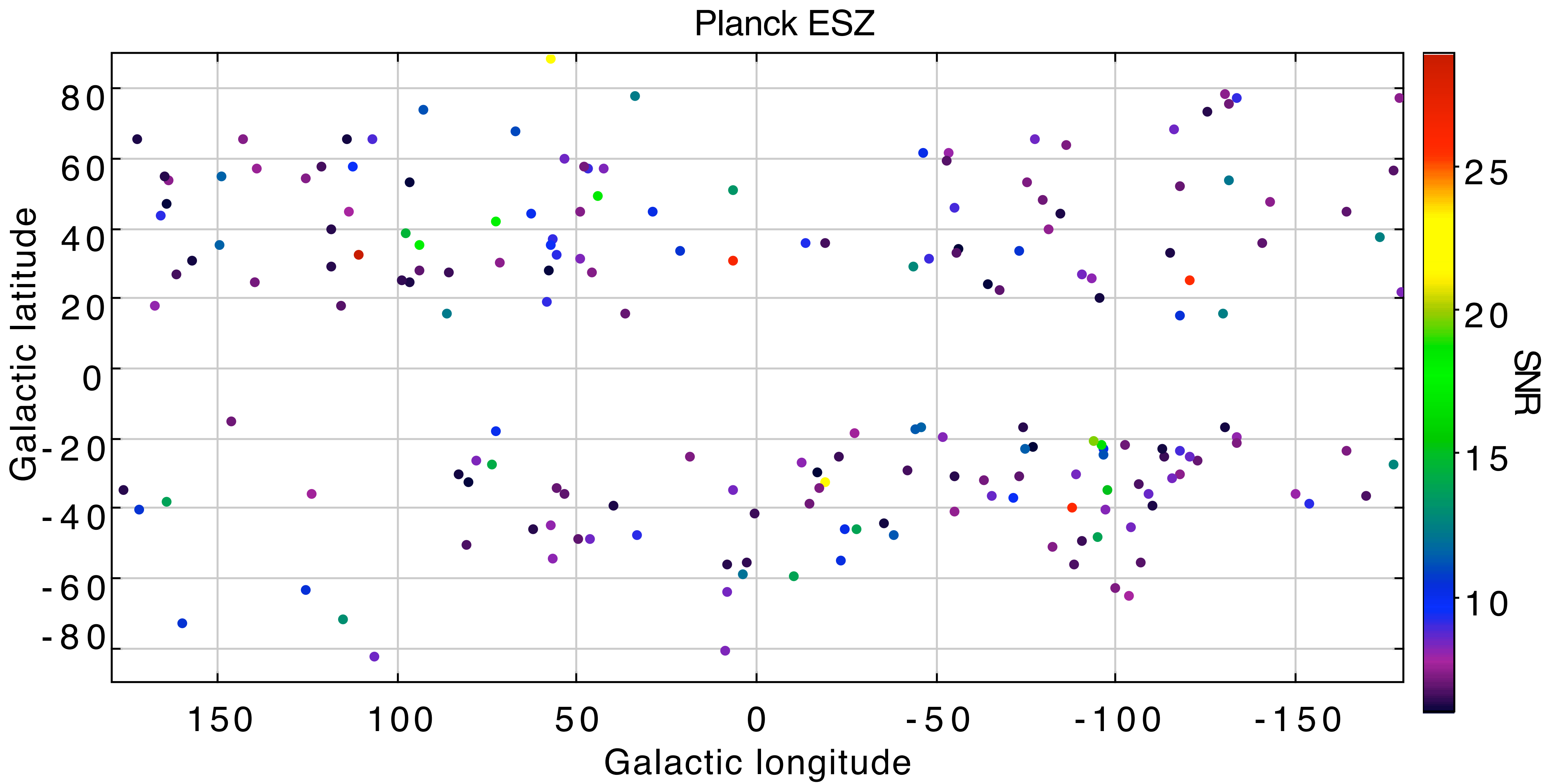


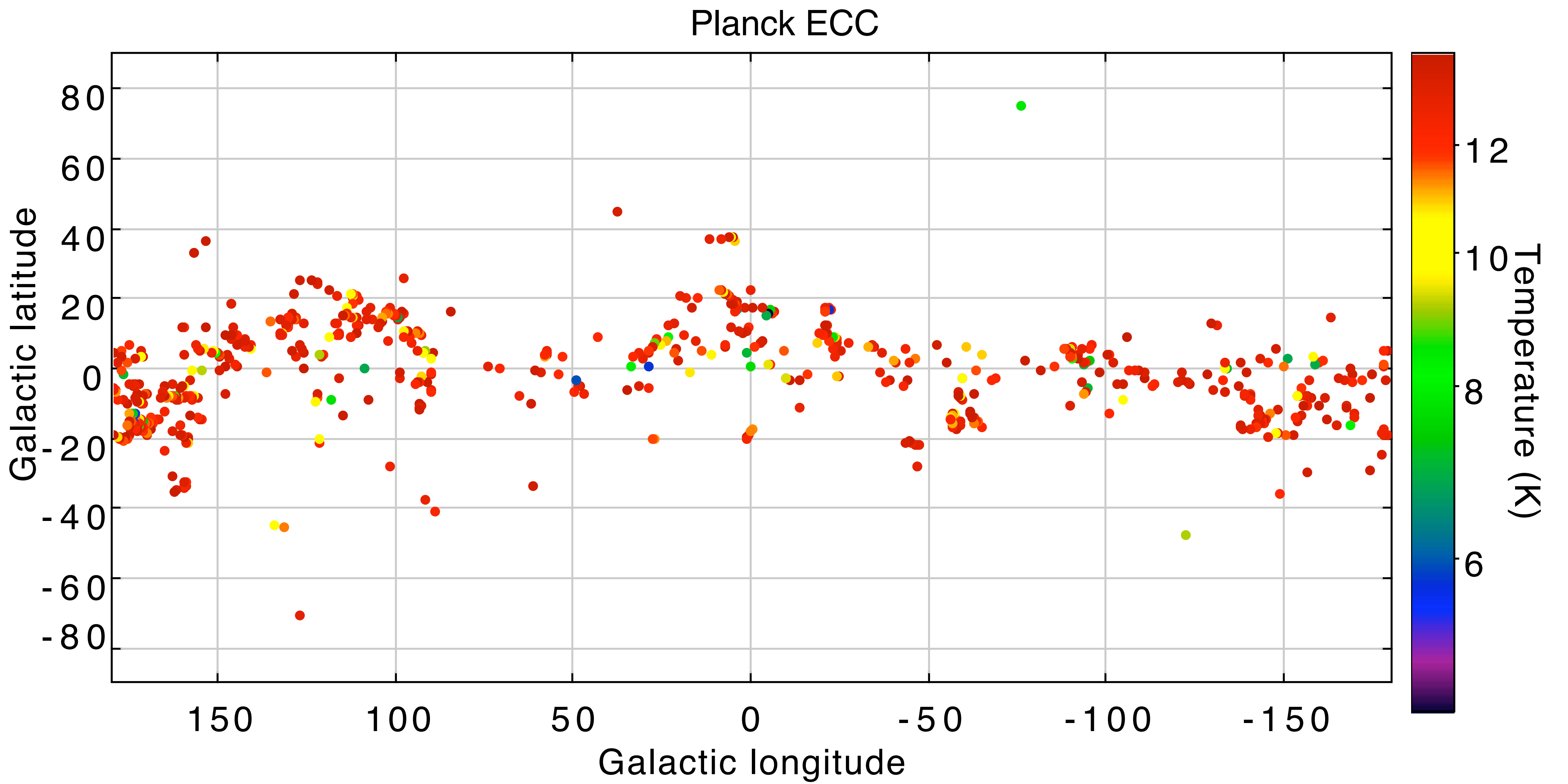
Planck ERCSC 353 GHz
Galactic latitude
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
Galactic longitude
Flux density (Jy)
1E3
100
10
1


Planck ERCSC 545 GHz
Galactic latitude
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
Galactic longitude
1E3
100
10
1
Flux density (Jy)



Planck ERCSC 857 GHz
Galactic latitude
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
Galactic longitude
1E4
1E3
100
10
1
Flux density (Jy)


Planck ESZ
Galactic latitude
Galactic longitude
SNR
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
25
20
15
10


Planck ECC
Galactic latitude
80
60
40
20
0
-20
-40
-60
-80
150
100
50
0
-50
-100
-150
Galactic longitude
Temperature (K)
12
10
8
6

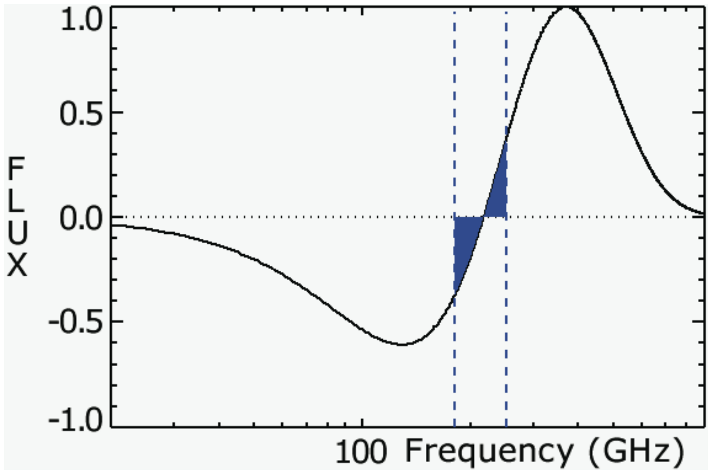
ERCSC Important Points

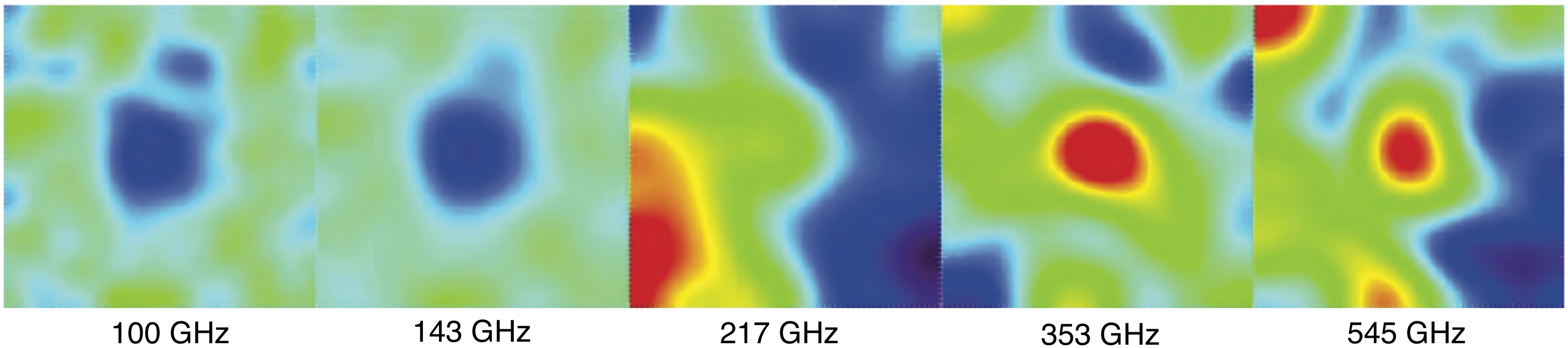
- Reliability is high (>90%), but there is no claim on completeness!!!!!!!!!!!!!!!!!!!!!
  - It is NOT a flux-density-limited or a complete sample at any level

    Noise level in the maps is a strong function of position. "Backgrounds" vary widely. Effective beams and resolution vary across the sky and widely with frequency.
- Flux densities are based on maps map from 1.6 sky coverages. They are averages!!!
  - Sources vary on timescales from a few hours to years.
  - Planck Quick Detection System (QDS; Aatrokoski et al. 2010) attempts to quantify variability. QDS info included in notes for some sources.
- CO lines enter the edges of 100 (especially) and 217 GHz bands.
  - In extreme cases CO may be 50& of the given flux density.
- Multiple photometry measures
  - FLUX, GAUFLUX, PSFFLUX, FLUXDET
  - Different strengths and weaknesses. We're not measuring points of light on a dark background!!!
- A significant fraction of sources in upper HFI bands could be associated with Galactic interstellar medium features or cirrus. IRAS 100 μm surface brightness and an EXTENDED=1 flag can be helpful in distinguishing "sources" from cirrus.

The Sunyaev-Zeldovich Effect

- Hot gas in a giant potential well dominated by dark matter beats up some of the CMB photons passing through on their way to us
- Distorts the otherwise nearly perfect "blackness" of the CMB spectrum. Null at 217 GHz. It is not accidental that one of Planck's frequency bands is at 217 GHz.





The SZ Effect — cont'd

- SZ effect depends on $n_e T$, whereas X-ray emission depends on $n_e^2 T^{1/2}$
- Therefore a combination of SZ and X-ray observations allows a determination of both n_e and T of the hot gas.

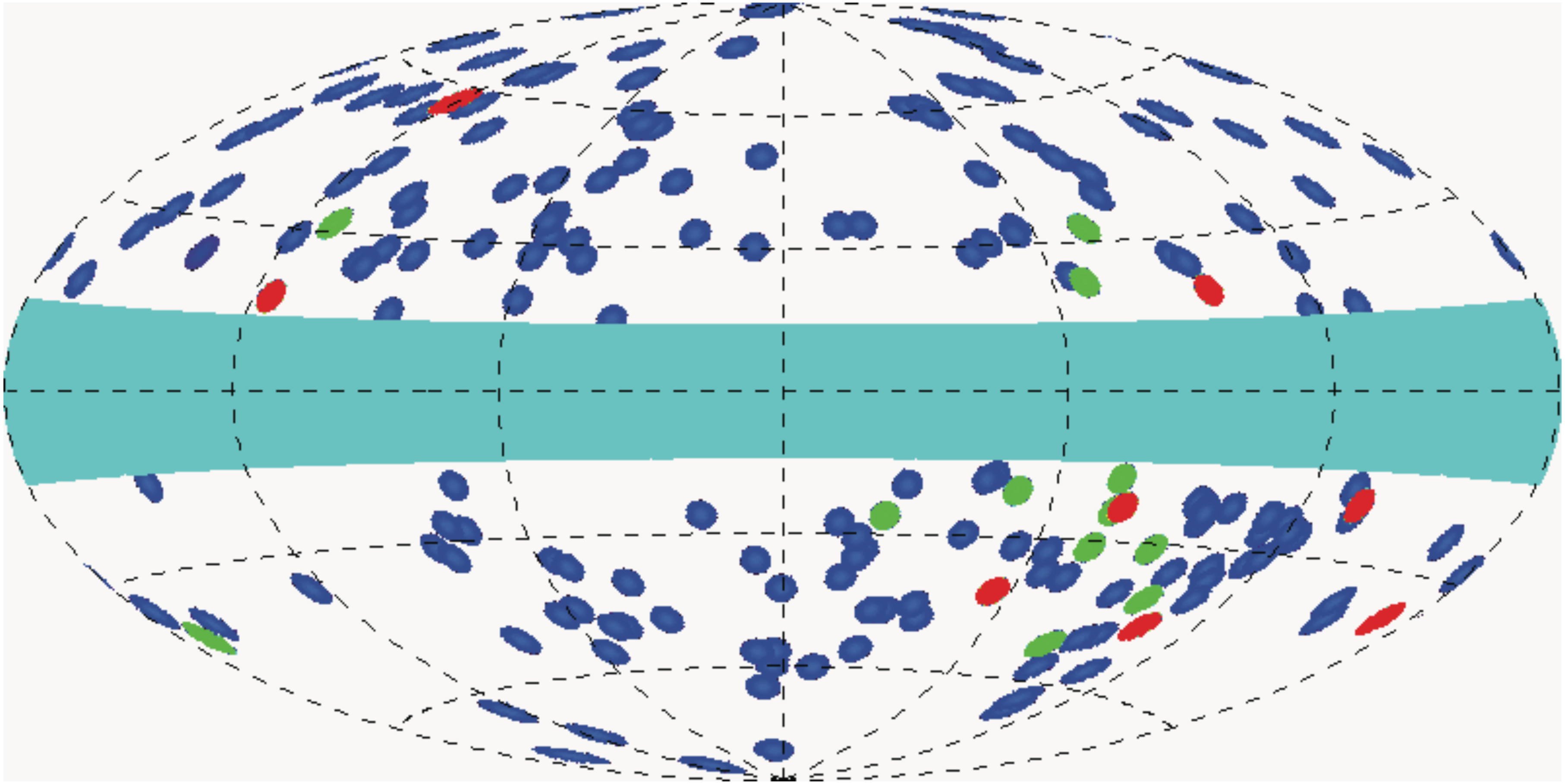
Planck ESZ

- The Planck SZ survey
  - Is the first all-sky cluster survey since ROSAT (1992)
  - Finds massive clusters, good for cosmology (3 figs. To follow in email from ESZ paper)
  - Is easy to follow-up (e.g., X-ray) once you know where to point!
- ESZ “firsts”
  - All sky SZ
  - Multiple frequency detections (6 bands around null)
- 189 clusters
  - 169 previously known (blue on next figure)
  - 20 of them not previously known

    12 confirmed: 11 by XMM; 1 by AMI/WISE (green on next figure)

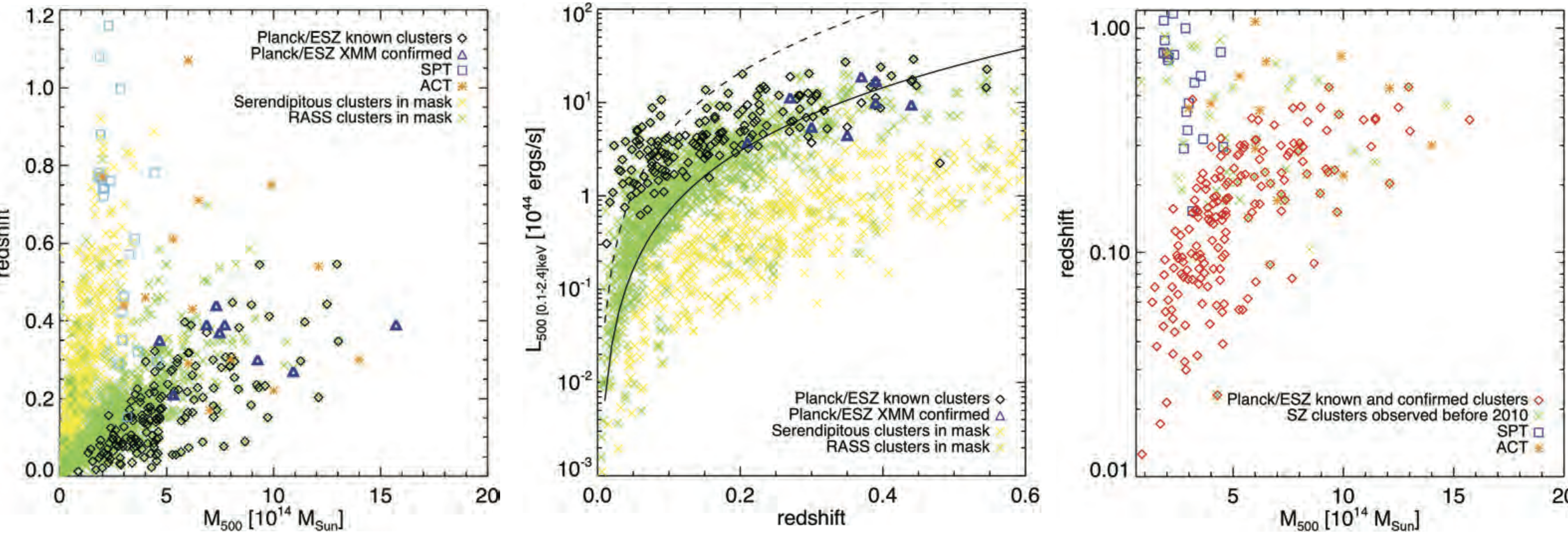
    8 to be confirmed (red on next figure)

SZ Clusters — ESZ



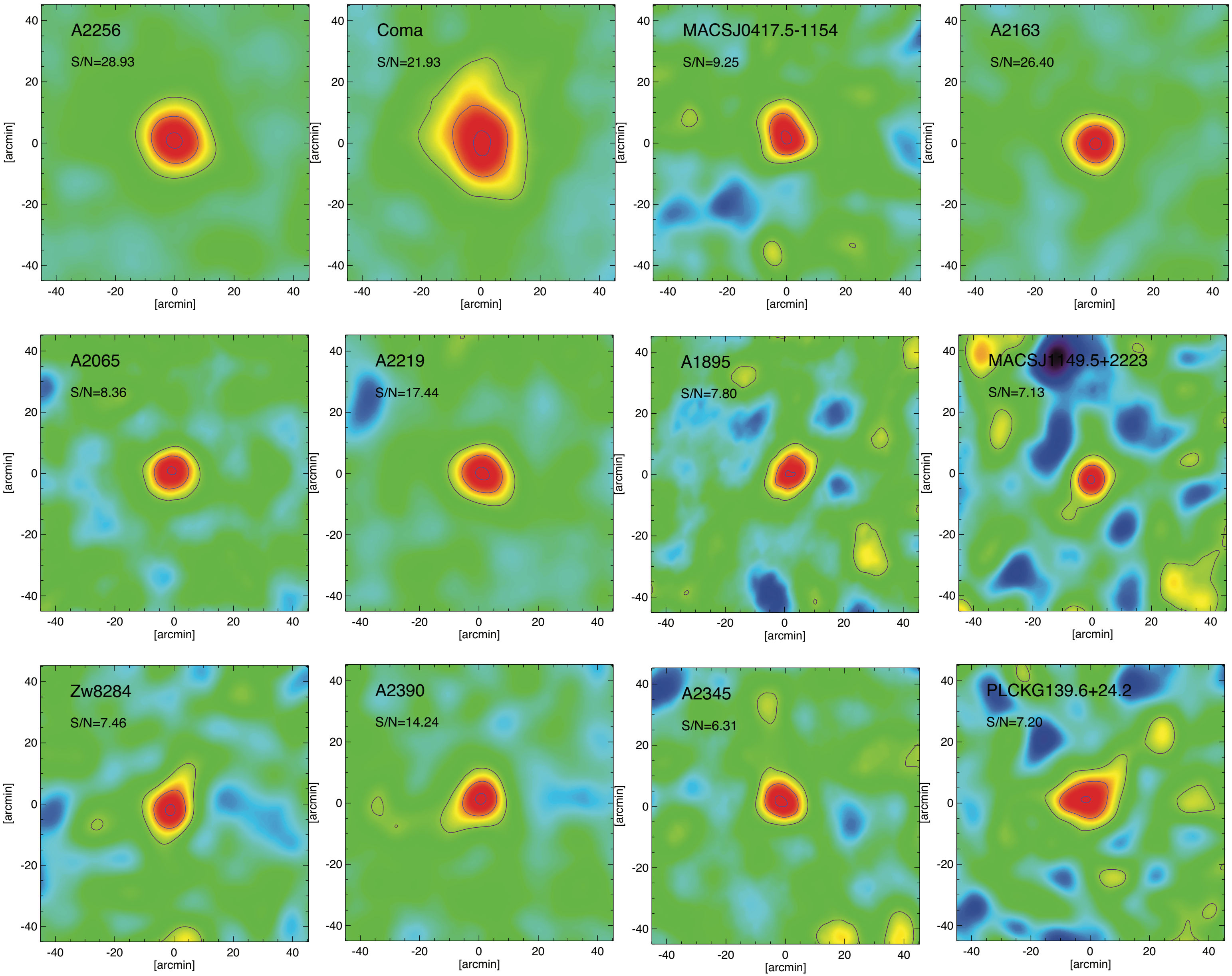
Planck ESZ

- Compare ESZ clusters with other samples



- At a given redshift, the ESZ clusters tend to be the most massive and X-ray luminous

ESZ Clusters — SNR



Stacking Analysis of MaxBCG Clusters

- Optical catalog
  - 13,823 clusters detected as red galaxy overdensities around bright central galaxies (BCGs)
  - 7,500 deg^2
  - Richness measure N_{200}, i.e., the number of red galaxies with $L > 0.4L_*$ inside the radius where density is 200 times the background density
  - Weak lensing calibrated mass-richness relations by Rozo et al. (2009)
- Planck data
  - 100–857 GHz
  - 10 months of data
  - Combine Planck data by richness (N_{200}) bins

SZ Clusters — Technicalities

- $H(z) = H_0 E(z) = (h \times 100\ \mathrm{km\,s^{-1}\,Mpc^{-1}}) E(z)$
- $R_\triangle$ is the radius inside of which the mean mass overdensity equals $\triangle \times \rho_c(z)$
  - $\rho_c(z) = 3H^2(z)/8\pi G$ is the critical density at redshift z
- $M_\triangle = \triangle(4\pi/3) R_\triangle^3 \rho_c$

N.B.—Optical cluster studies, esp. MaxBCG group, frequently use radii and masses scaled to the mean matter density, e.g., $R_{200\mathrm{b}}$ rather than the critical density.

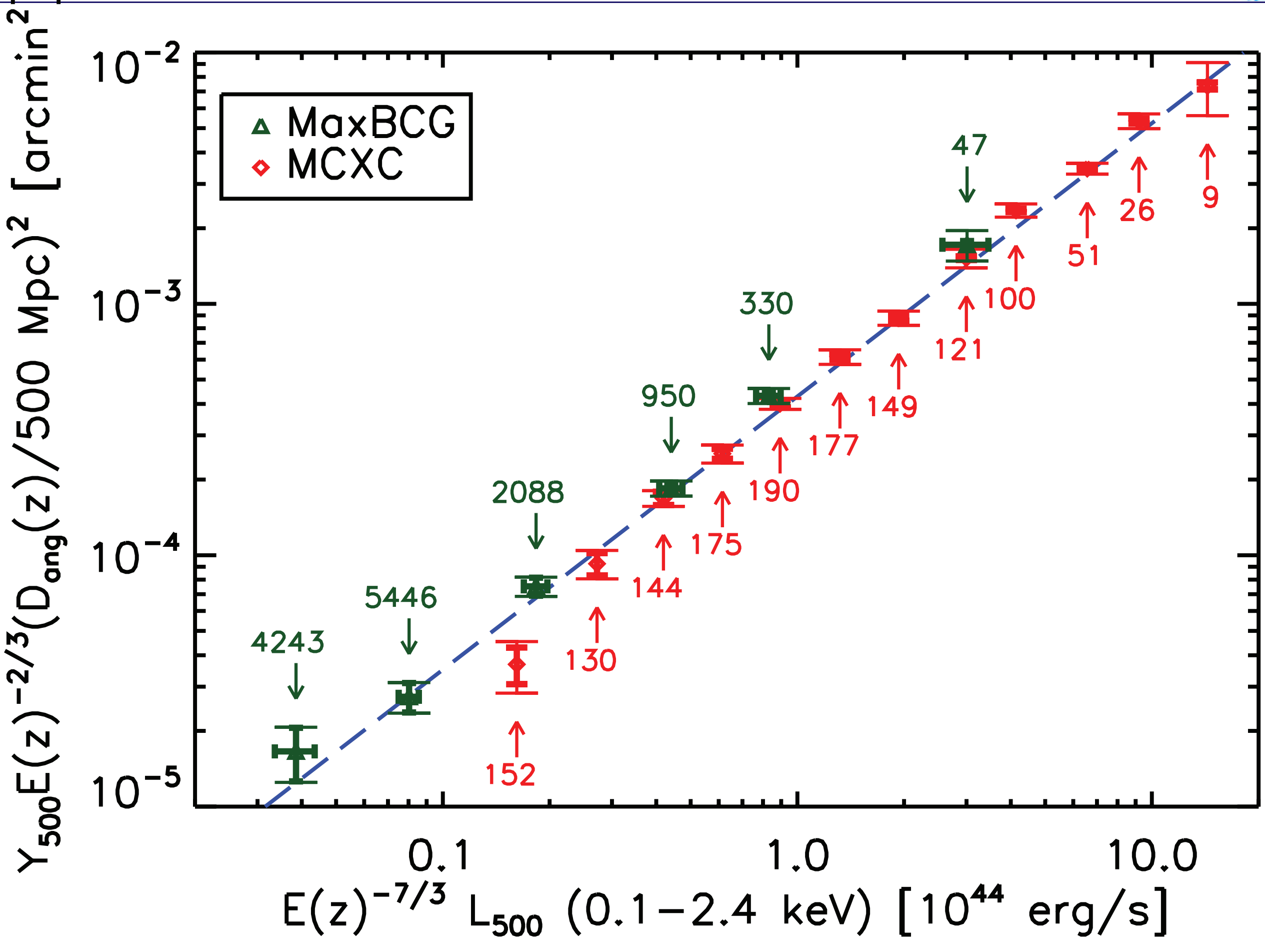
- For richness we use the MaxBCG N_{200}, defined as the number of red galaxies with $L > 0.4 L_*$ within $R_{200\mathrm{b}}$.
  - Richness is the only quantity we define relative to the mean background density.
- Characterize SZ signal with Compton y parameter integrated over a sphere of radium R_{500}, expressed in arminutes^2

$$Y_{500} = (\sigma_\mathrm{T}/m_e c^2) \int_0^{R_{500}} P dV / D_\mathrm{A}^2(z)$$

  - Spherical rather than cylindrical quantity possible because we adopt a template SZ profile when using the matched filter
- Bring to $z = 0$ and a fiducial angular distance assuming self-similar scaling in redshift.

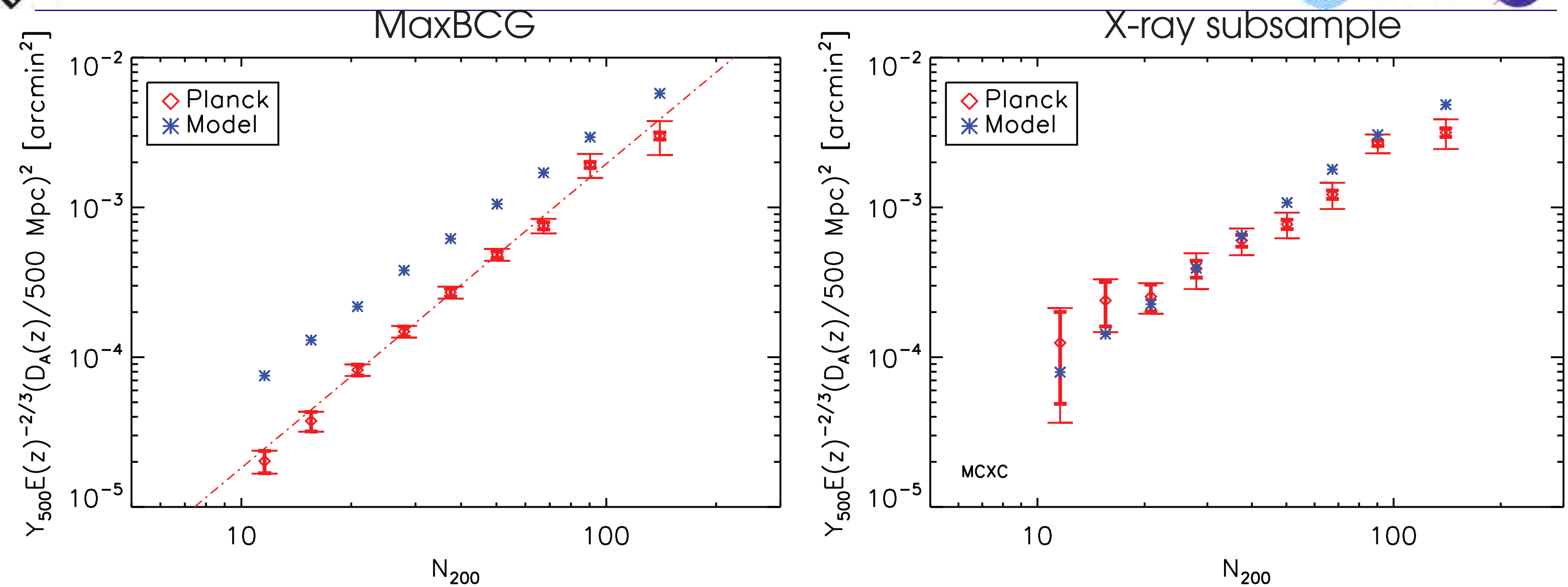
$$\tilde{Y} \equiv Y_{500} E^{-2/3}(z) \left(\frac{D_\mathrm{A}(z)}{500\,\mathrm{Mpc}} \right)^2$$

SZ Clusters — Planck & MaxBCG



- SZ-X-ray: agree with theoretical predictions; i.e., Y-L_X good match at all masses
  - X-rays for MaxBCG sample from RASS stacking analysis by Rykoff et al. 2008
- SZ-Optical: SZ signal detected down to low-mass systems. Lower than ever before.

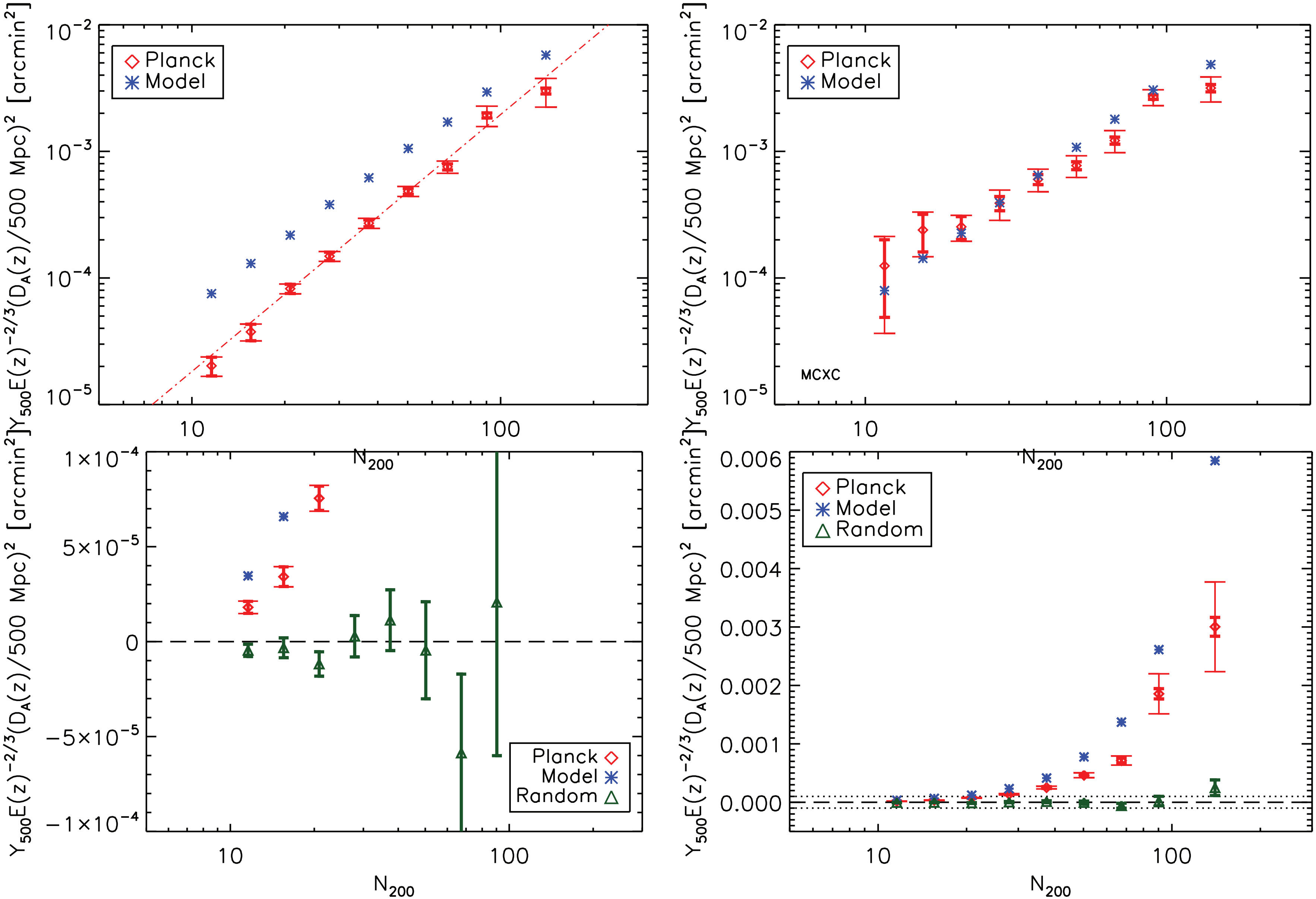
SZ Clusters — Planck & MaxBCG



- SZ-Optical:
  - SZ signal detected down to low-mass systems. Lower than ever before.
  - Y-richness relation discrepant with model for whole sample

    Model: Y-M (X-ray Arnaud et al. 2010); M-N_{200} (weak lensing Rozo et al. 2009)
  - But not discrepant for X-ray subsample
- Don't understand the origin of the discrepancy
  - Sub-populations in cluster population?
  - Ongoing work

SZ Clusters — Planck & MaxBCG



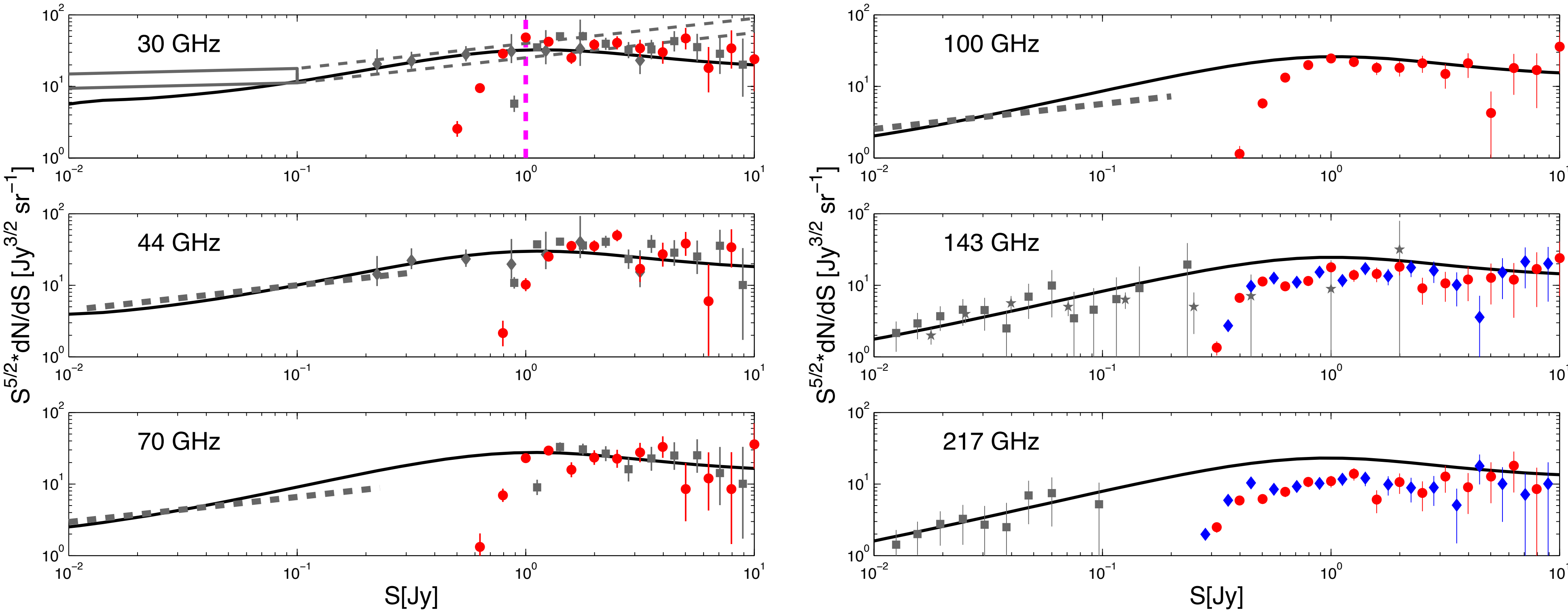
Ex-gal Radio Srces — Statistical Properties

- The wide simultaneous frequency coverage in the ERCSC offers an opportunity to study extragalactic radio sources over a frequency range never before explored in blind surveys.
- Sample chosen at 30 GHz
  - Extensive validation activity showed that $> 97\%$ of ERCSC sources have reliable counterparts in published catalogues at GHz frequencies.
  - To minimize Galactic contamination:

    $|b| > 5^\circ$

    Exclude Magellanic Clouds and 18 known Galactic objects
  - 533 extragalactic sources
  - Various tests show sample complete above $S > 1.0$ Jy

30 GHz Complete Sample — Source Counts

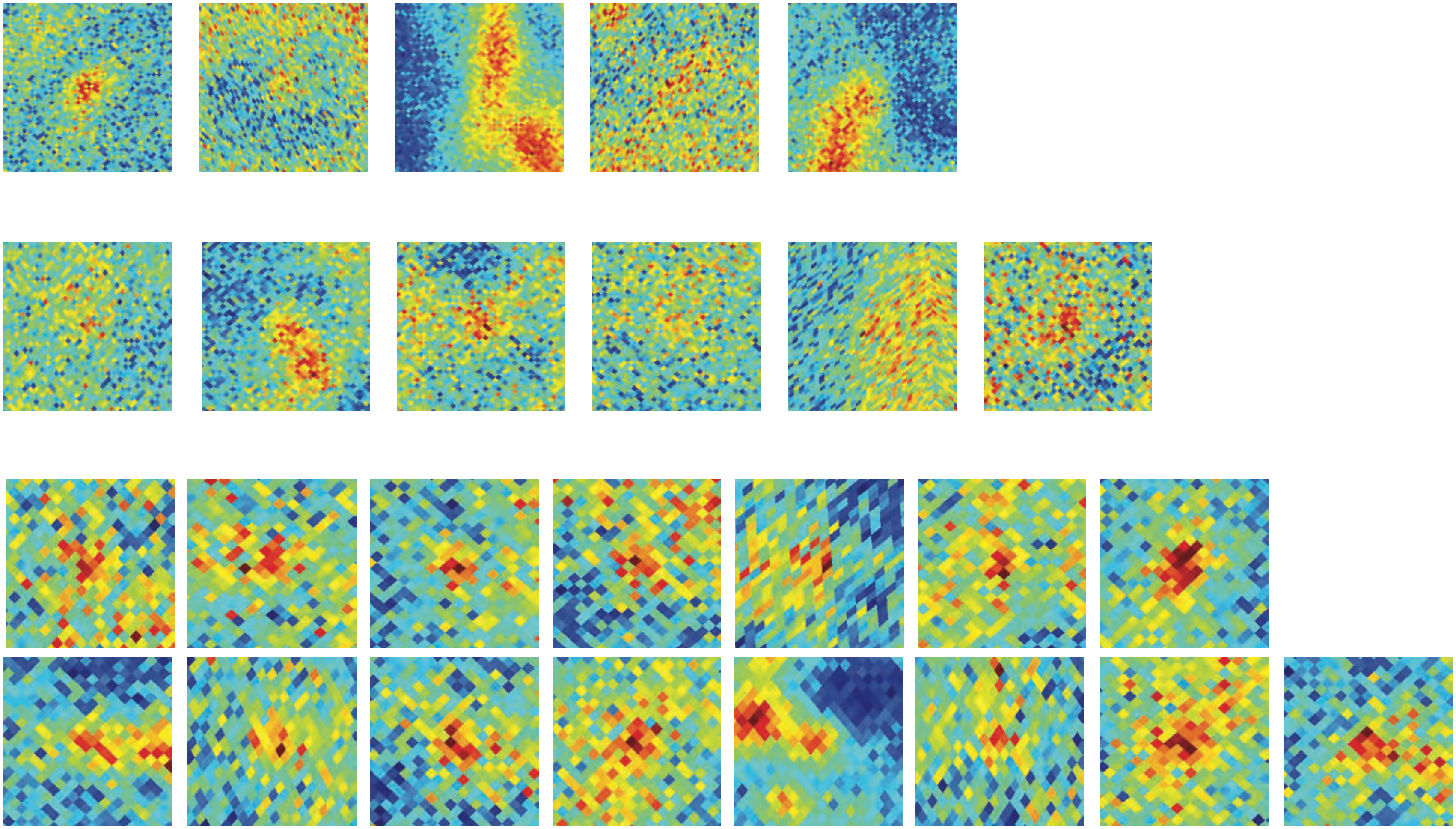


red = Planck
grey box = VSA
grey dashed box = DASI
grey squares = WMAP
grey dashed line = counts by Waldram
solid curves = de Zotti model

red = Planck
blue diamonds = remove sources with α_{143}^{217} "dusty"
grey squares = SPT
grey dashed line = counts by Waldram
solid curves = de Zotti model

- de Zotti model overpredicts bright-end counts at 143 and 217 GHz by factors of 2 and 2.6, respectively

Validation and Extreme Radio Sources



- Unidentified ERCSC sources at 30 (top), 44 (middle), and 70 (bottom) GHz
  - Most are likely associated with Galactic or extended extragalactic objects

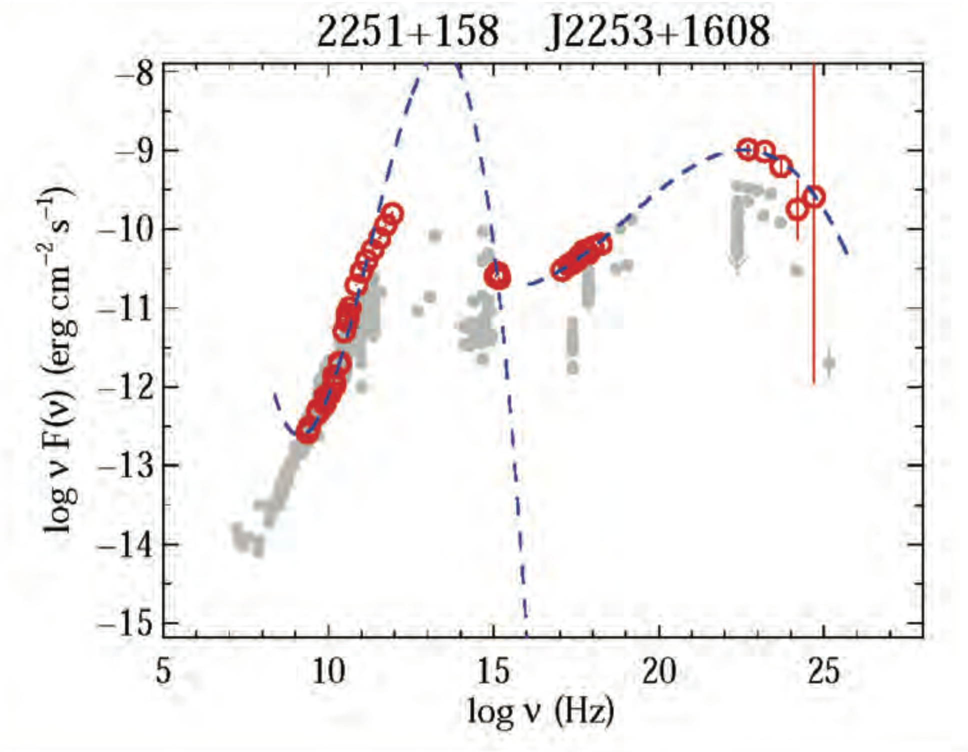
Validation and Extreme Radio Sources — cont'd

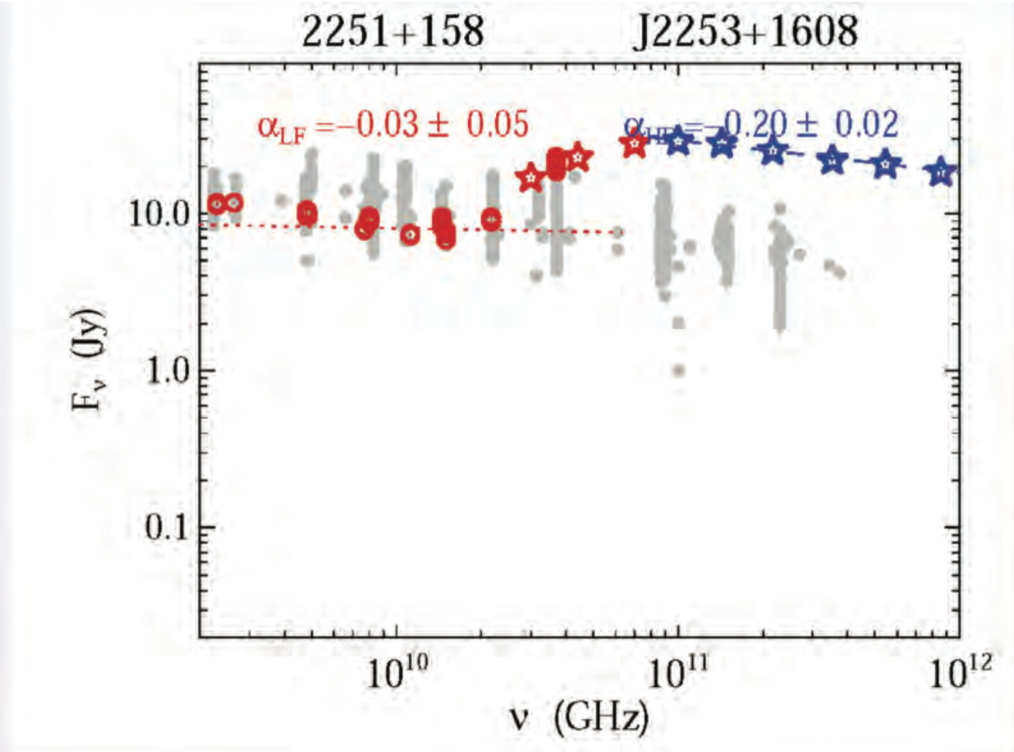
- Vast majority of extragalactic ERCSC sources have relatively flat radio spectra ($\alpha > -0.5$) extending up to and sometimes beyond 143 GHz
- A small fraction of sources show peaked/convex spectra, mostly identified as blazars.
- Known examples of compact, newborn radio galaxies (CSOs) are generally too faint for Planck.
- Essentially all EG sources detected at 100, 143, and 217 GHz are synchrotron-dominated radio sources, not dusty galaxies.
- No compelling evidence for any new class of EG radio sources

SEDs of EG Radio Sources

- Planck ERCSC observations 30–857 GHz
- Complemented by simultaneous multifrequency data, from radio to γ-rays.
- Radio: Metsähovi, UMRAO, RATAN-600, OVRO, Effelsberg, IRAM, VLA, APEX, ATCA, Medicina
- Optical: KVA, Xinglong, Swift UVOT
- X-rays and γ-rays: Swift XRT, Fermi-LAT
- SEDs of 104 sources

3C454.3

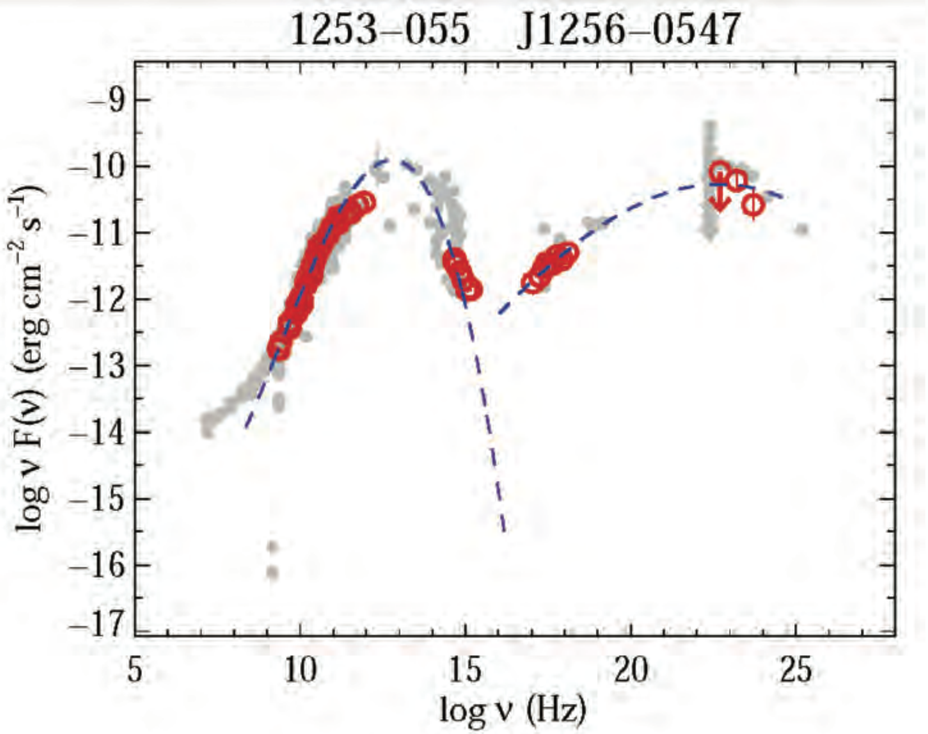




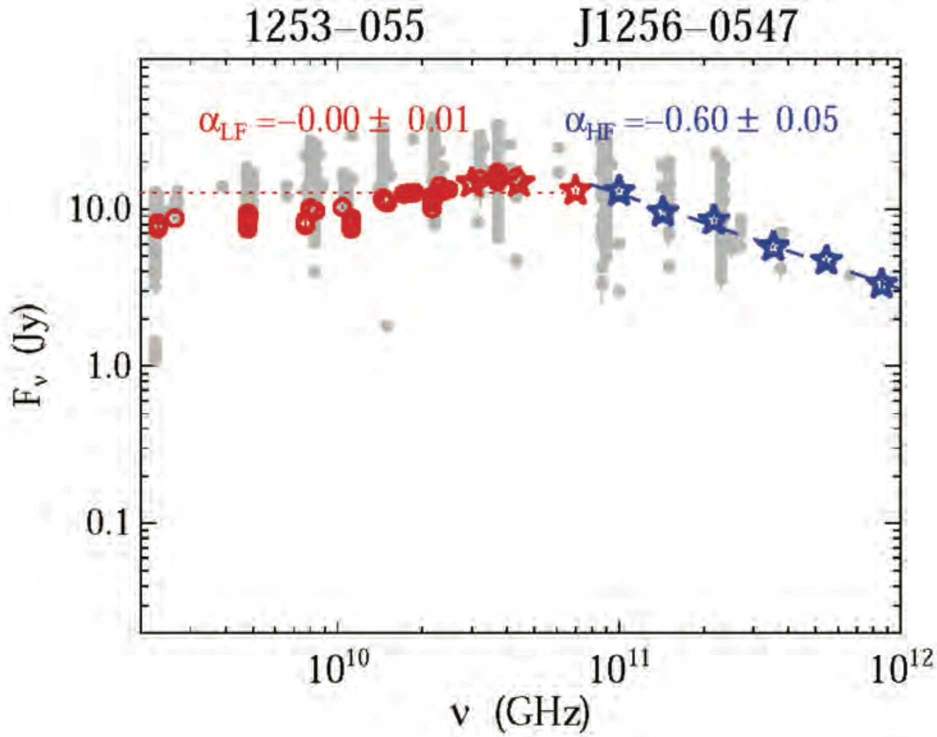
grey points = historical data
red = data simultaneous with Planck

blue stars = Planck HFI
red start = Planck LFI
red circles = data simultaneous with Planck

3C279

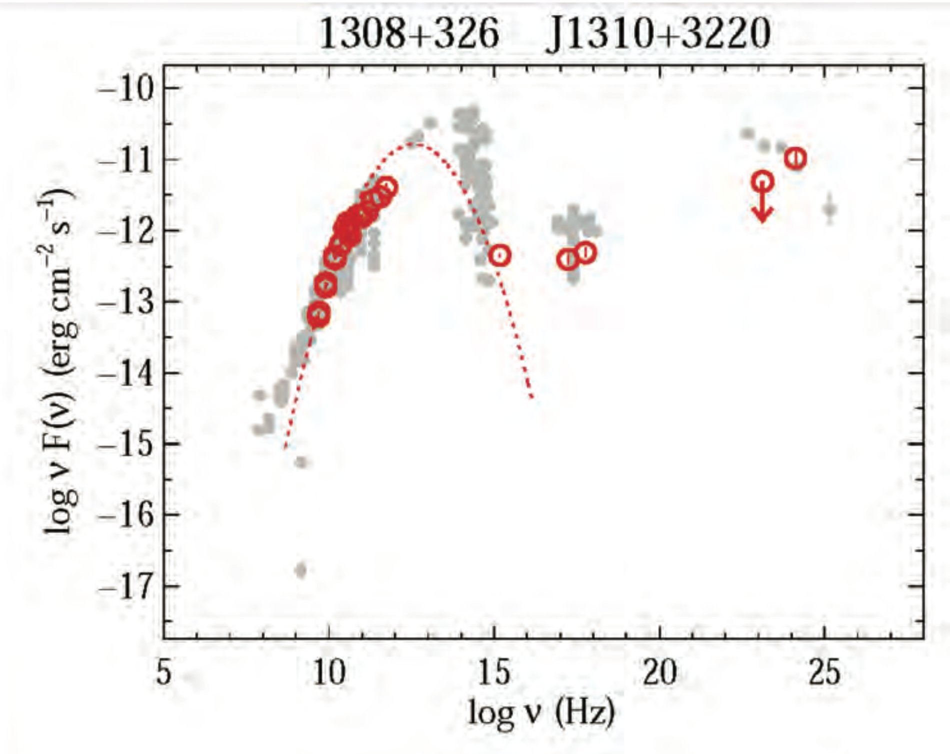


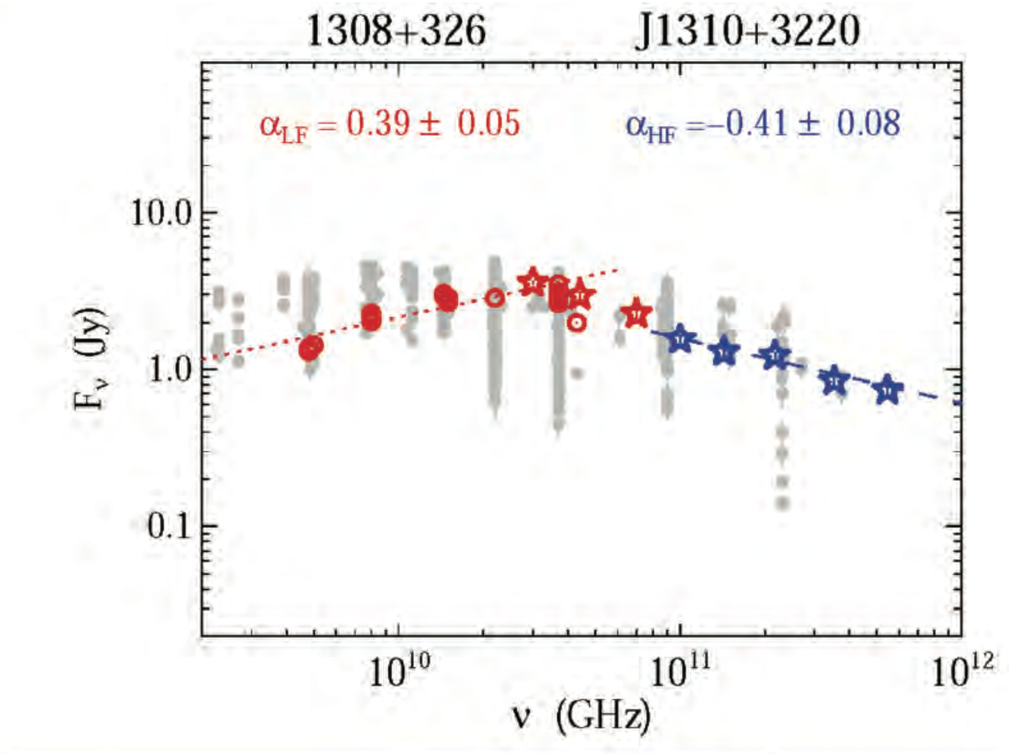
1253–055 J1256–0547
log ν F(ν) (erg cm^{-2} s^{-1})
log ν (Hz)



1253–055 J1256–0547
α_{LF} =–0.00 ± 0.01
α_{HF} =–0.60 ± 0.05
F_ν (Jy)
ν (GHz)

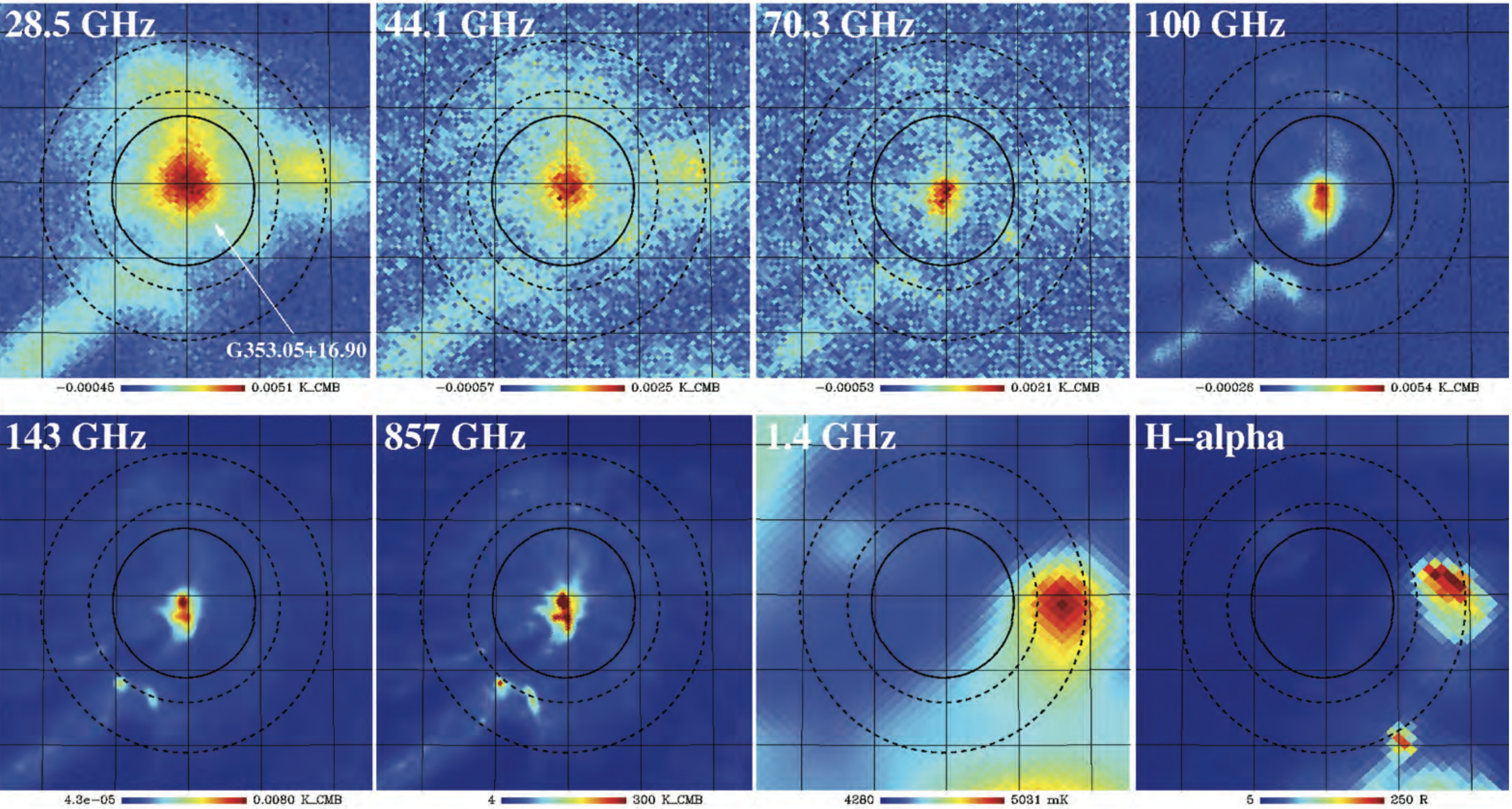
1308+326



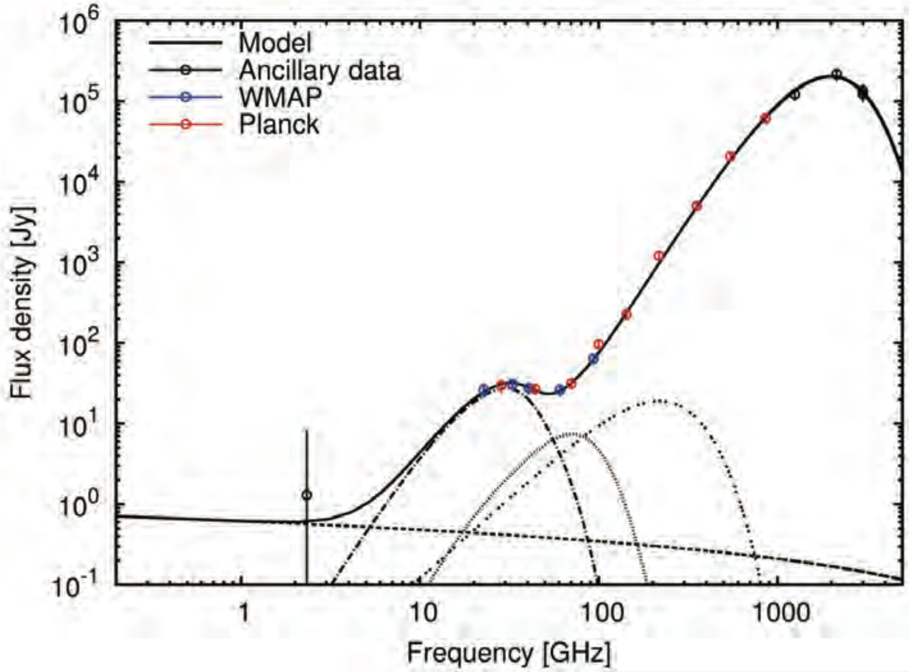


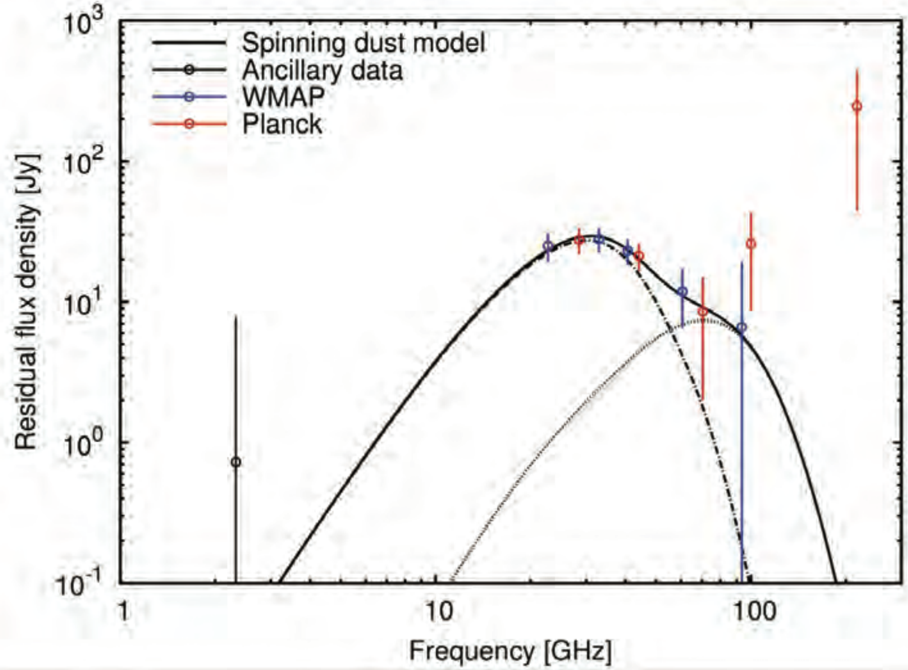
- Variability is a big factor. Simultaneous observations make a huge difference.
- There is a significant indication that the high frequency Planck objects have a very hard original electron spectrum.

rho Ophiucus & Spinning Dust



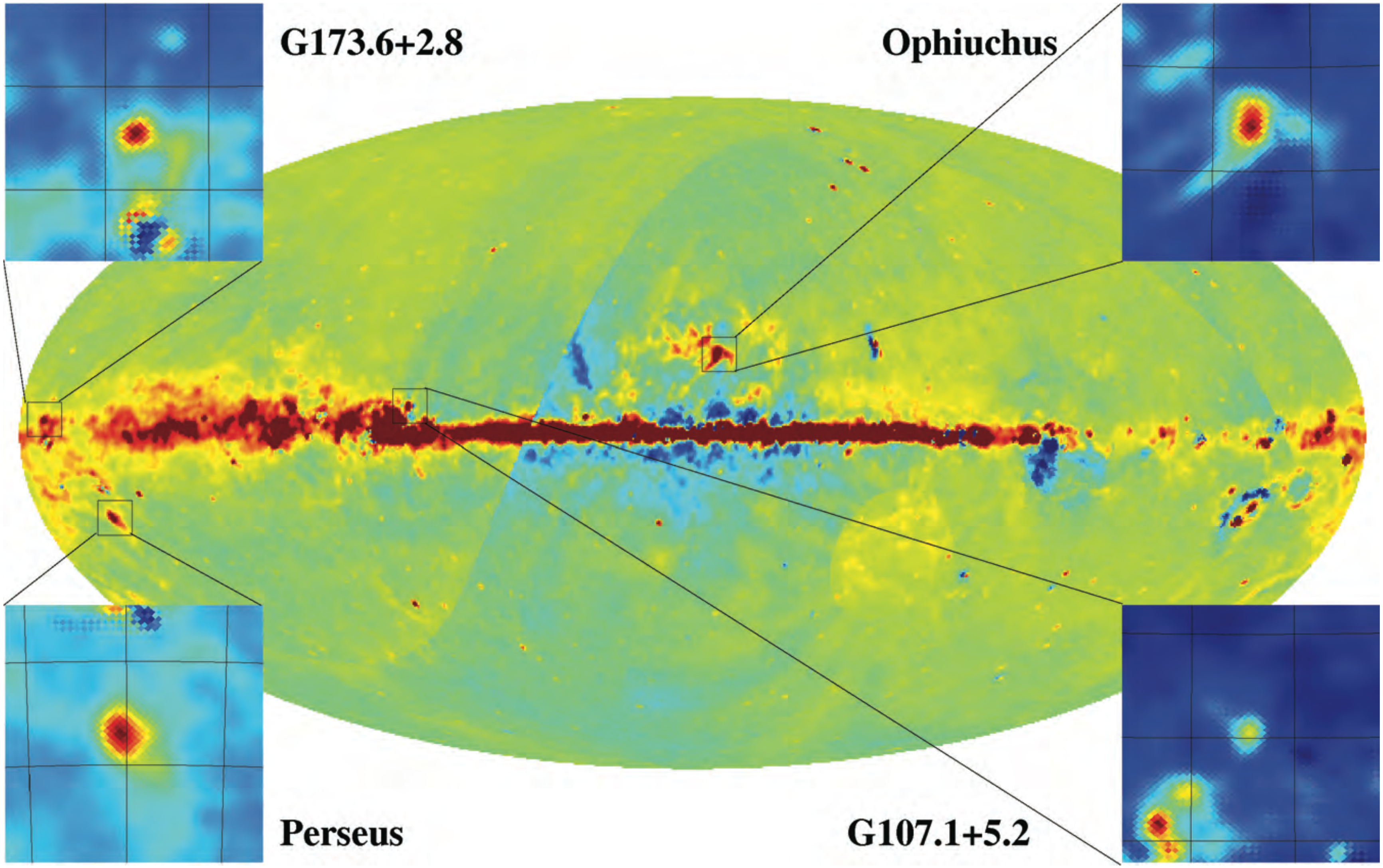
rho Ophiucus & Spinning Dust





- Fit free-free, CMB, thermal dust spectra
- COSMOSOMAS showed rising spectrum from 10–15 GHa
- Planck's high frequency coverage nails the thermal dust spectrum, leaving a nice spinning dust spectrum, well-fit with a 2-component high density molecular gas + irradiated low density atomic gas model.

More Spinning Dust

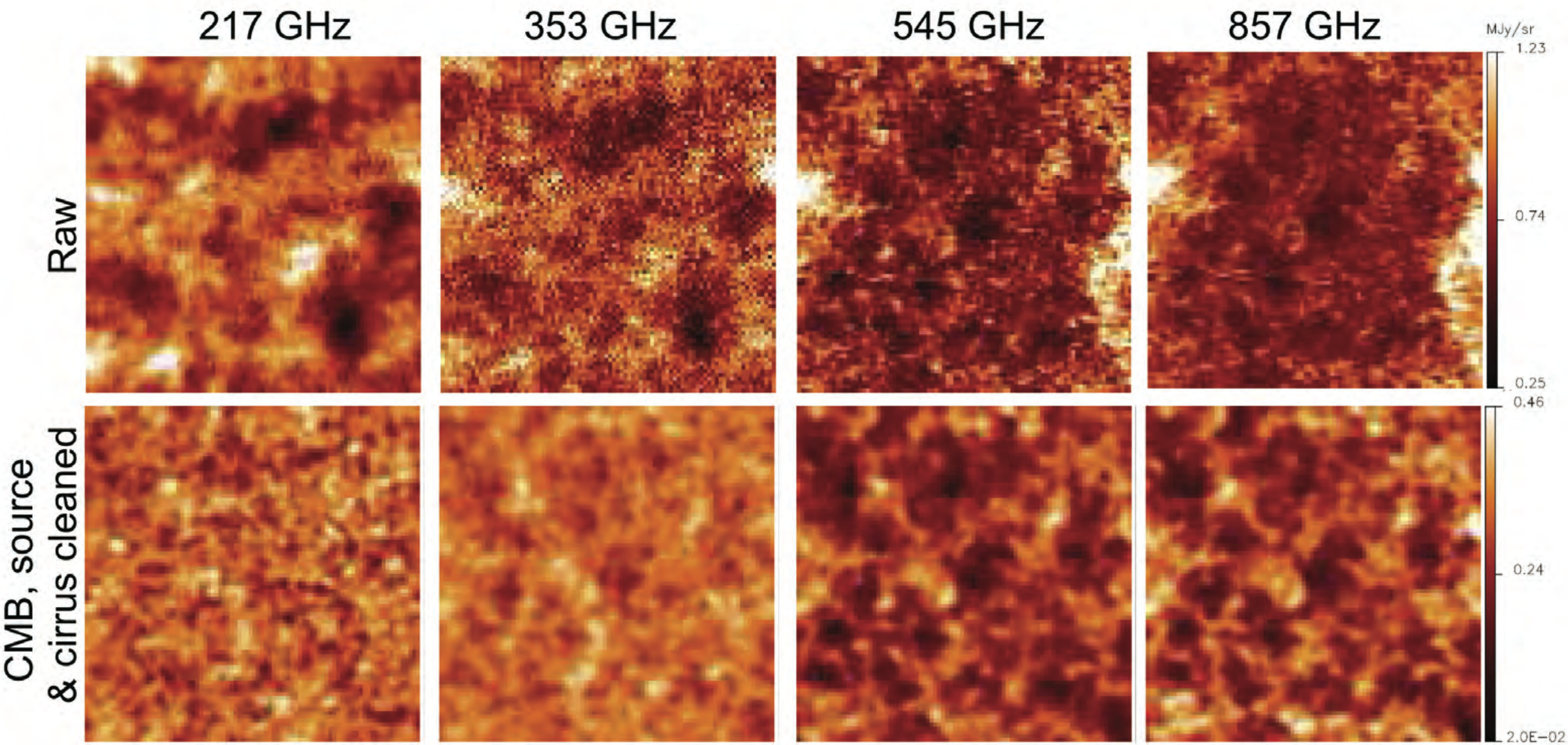


- New regions of "anomalous microwave emission". It's everywhere!

Cosmic Infrared Background Anisotropies

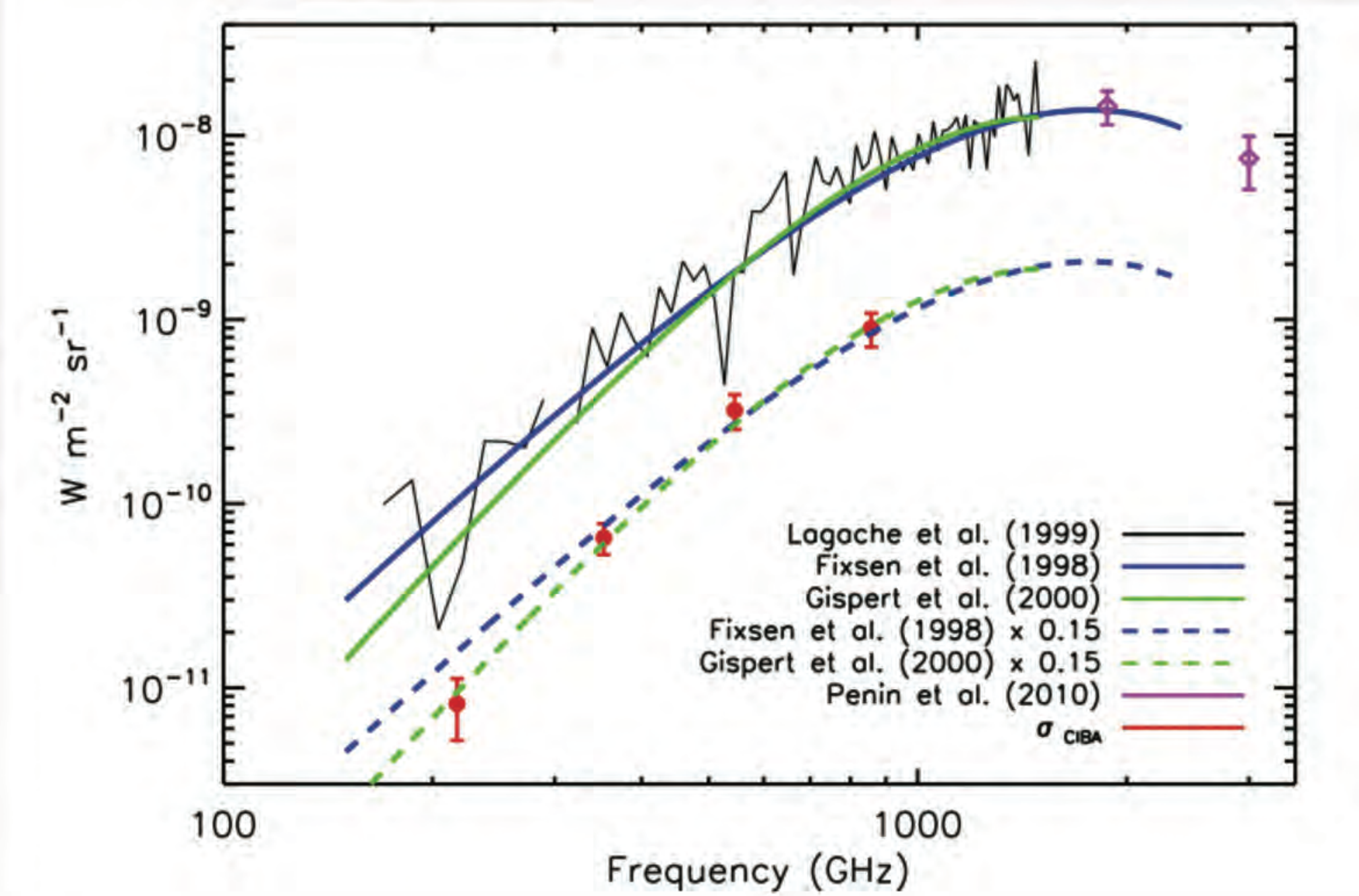
- The CIB represents the cumulative emission of high-z, dusty, star- forming galaxies.
- It's an important probe of much of star-formation in the Universe.
- Maps are highly correlated at high frequencies.
- Decorrelation at low frequencies is expected as sources at different zs dominate low frequency maps.
- Significant detection of CIB anisotropy, with spectrum consistent with CIB mean, over a broad range of scales.
- Compares well with previous measurements at smaller angular scales.

CIB — cont'd



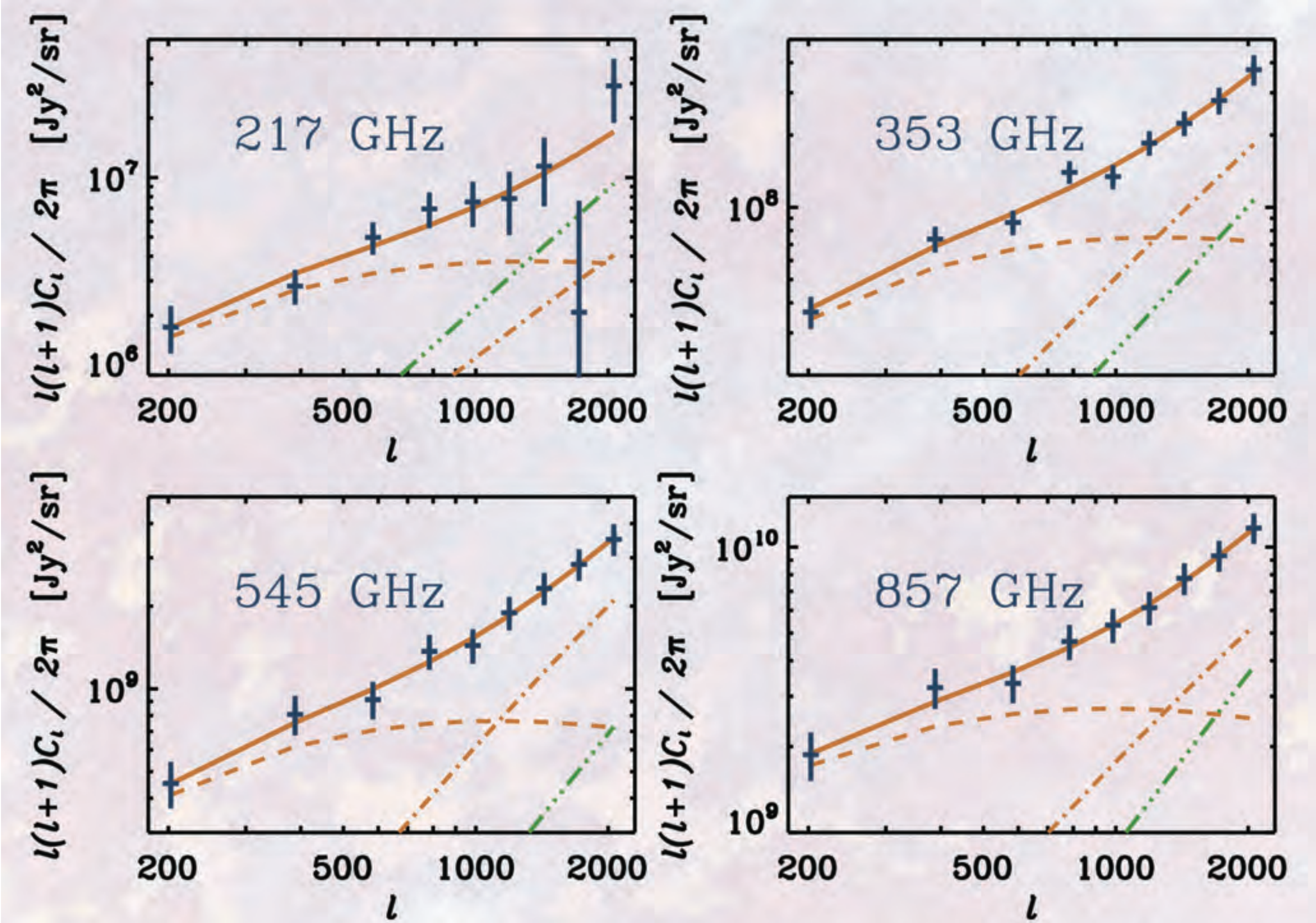
- Residual map = Planck Raw − Planck CMB − Planck sources − Cirrus (HI)
- Residual shows fluctuations correlated by bands: the CIB!

CIB — cont'd



- Spectrum of CIB mean matches that of CIB anisotropy.
  - Consistent with galaxies dominating mean also generating anisotropy.

CIB — cont'd



- Power spectra at each of four frequencies:
  - Clear detection of clustering of sources of CIB anisotropy.
  - Large dynamic range probes both linear and non-linear scales.

    combination will be powerful for modeling sources (and Herschel will extend).

Cold Cores/Clumps

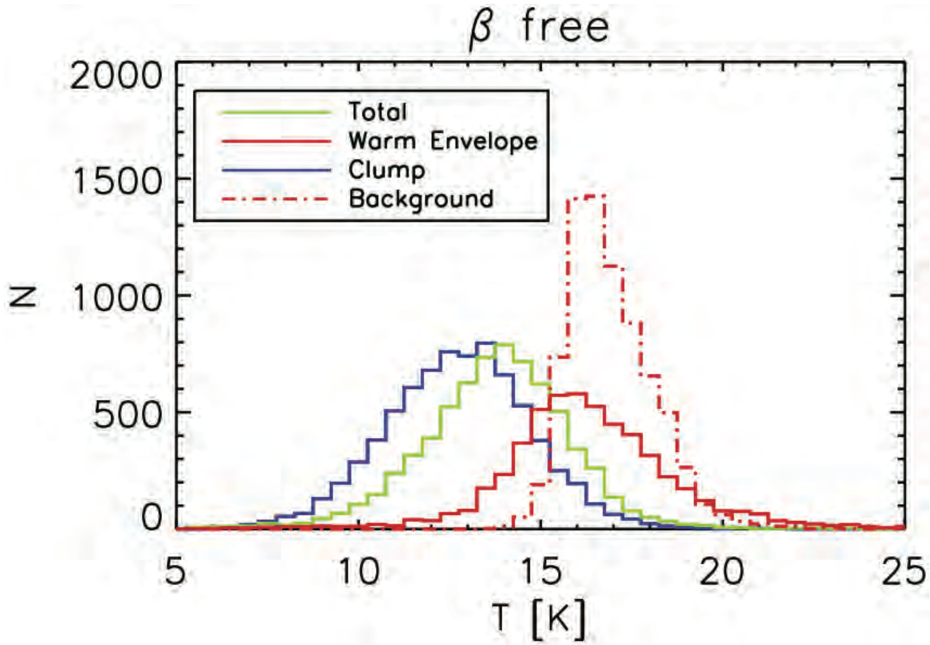
- Apply dedicated source extration algorithm to the Planck data + IRAS 100 μm data
- Find 10783 cold compact objects — the Cold Core Catalogue of Planck Objects (C3PO)
- Apply two criteria determined from Monte Carlo Quality Assessment to ensure a list of cold cores that is $\geq 90\%$ reliable
  - SNR > 15
  - $T < 14$ K
  - Released today as the Early Cold Cores list

    915 objects suitable for follow-up with Herschel, ALMA, SOFIA, VLA, etc.

- A small group of Planck-selected cold cores has been observed with Herschel in a Key Project program

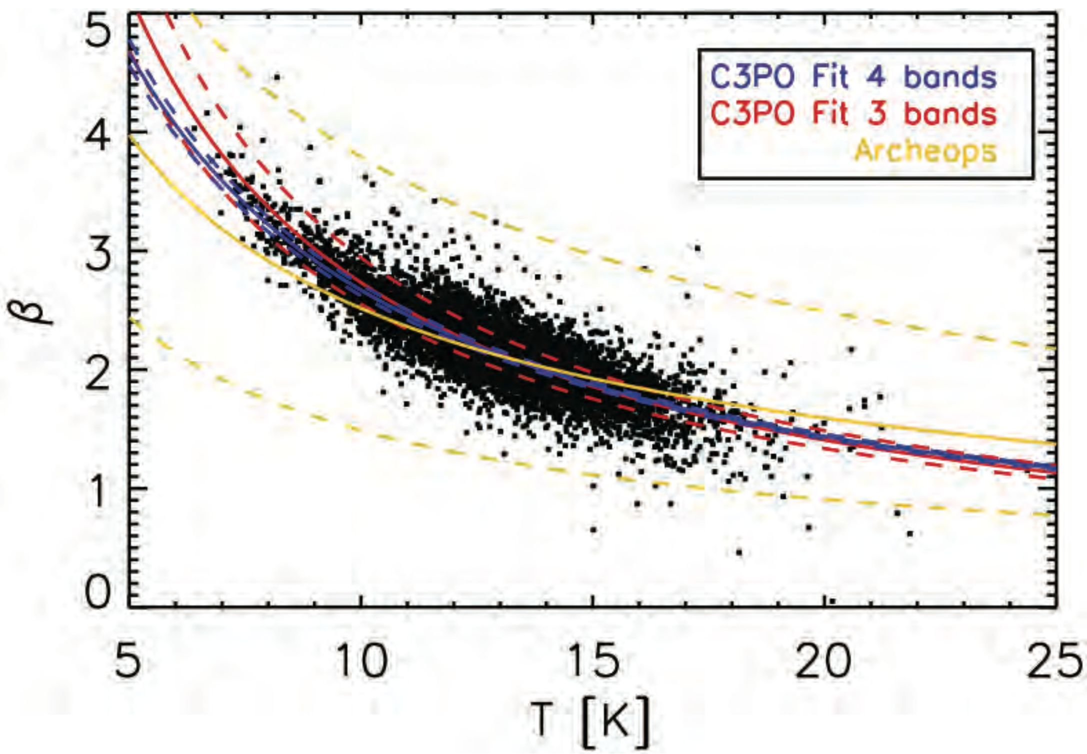
N.B.—For historical reasons, we use "Cold Cores" to designate the entries in the ECC, since pre-stellar cores were a major scientific goal of this product. However, as two companion papers (Planck Collaboration 2011r,s) demonstrate, most of these entries are more correctly described as "cold clumps", intermediate in their structure and physical scale between a true pre-stellar core and a molecular cloud.

Cold Core Population Characteristics



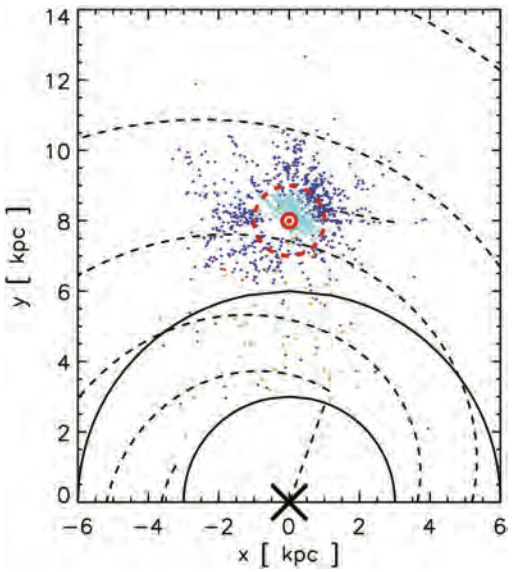
- Roughly doubles the number of cold cores/clumps known
- Distributed all over the sky, mainly around the Galactic plane, and highly correlated with the Galactic molecular component CO
- Lowest temperatures of 7 K the coldest ever seen
- Temperatures from 7 to 17 K, with peak at 13 K

Cold Core Population Characteristics — cont'd



- Spectral index β varies over the whole range of temperature, from 1.4 to 2.8

Cold Core Population Characteristics



Quantity	min	<>	max
T_C [K]	7	13	17
$N_H[Hatom.cm^{-2}]$	10^{20}	$2 \cdot 10^{21}$	$2 \cdot 10^{23}$
Size [pc]	0.2	1.2	18
Ellipticity	0.4	0.8	1
Mass [$M_\odot$]	0.4	88	24000
Mean density [cm^{-3}]	10^2	$2 \cdot 10^3$	10^5

- Distances determined for 2619 objects, from extinction and associations with known molecular complexes and infrared dark clouds.
- Most of the objects are located in the local neighborhood, within 2 kpc.
- Physical properties size, mass, density, column density, and luminosity lead to designation as "cold clumps" rather than cold cores.
- Mainly organized in groups and filaments, and preferentially are aligned on large scale loops.

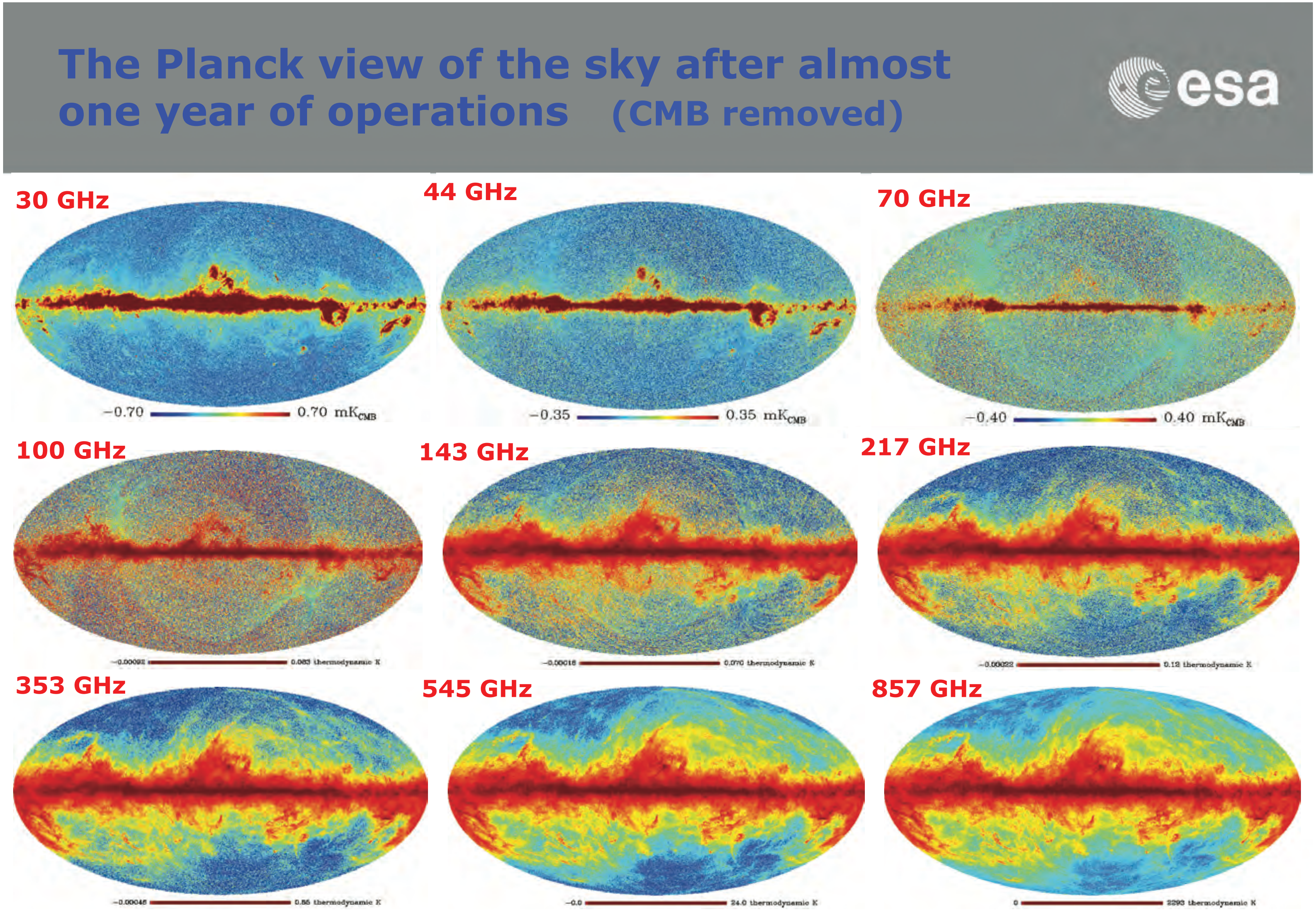
ECC

- Time for some follow-up observations. Start writing proposals!

Summary

- Planck observations began on 13 August 2009, and have continued without interruption until now
- Although built for cosmology, Planck has capabilities that make it useful for a wide range of astrophysics investigations
  - All-sky
  - Frequencies from 30 to 857 GHz simultaneously
  - Above 100 GHz opens up large phase space
  - Limited angular resolution ($4'$– $31'$), but excellent sensitivity
- Today I had to leave out more than I could cover, but the papers tell the story.
- It will take another two years for us to understand and control systematics at the level required for the CMB science, but the ERCSC is available now to everyone for follow-up studies on a wide range of objects.

Foregrounds at Nine Frequencies



esa

planck

cnes

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NASA

cnrs

DTU Space
National Space Institute

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HFi PLANCK
a look back to the birth of Universe

PLANCK LFI

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CSIC
Consejo Superior de Investigaciones Científicas

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University of Sussex

Early Astrophysics Results from

PLANCK

Caltech

7 March 2011

Graca Rocha, JPL

for the Planck Collaboration