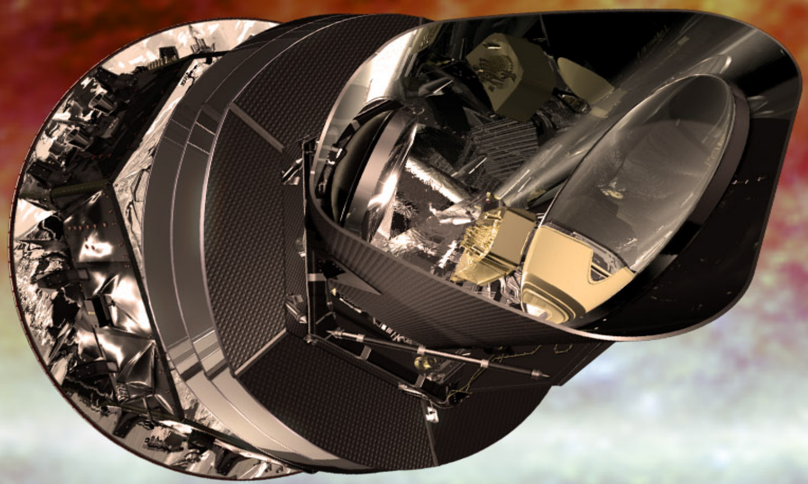
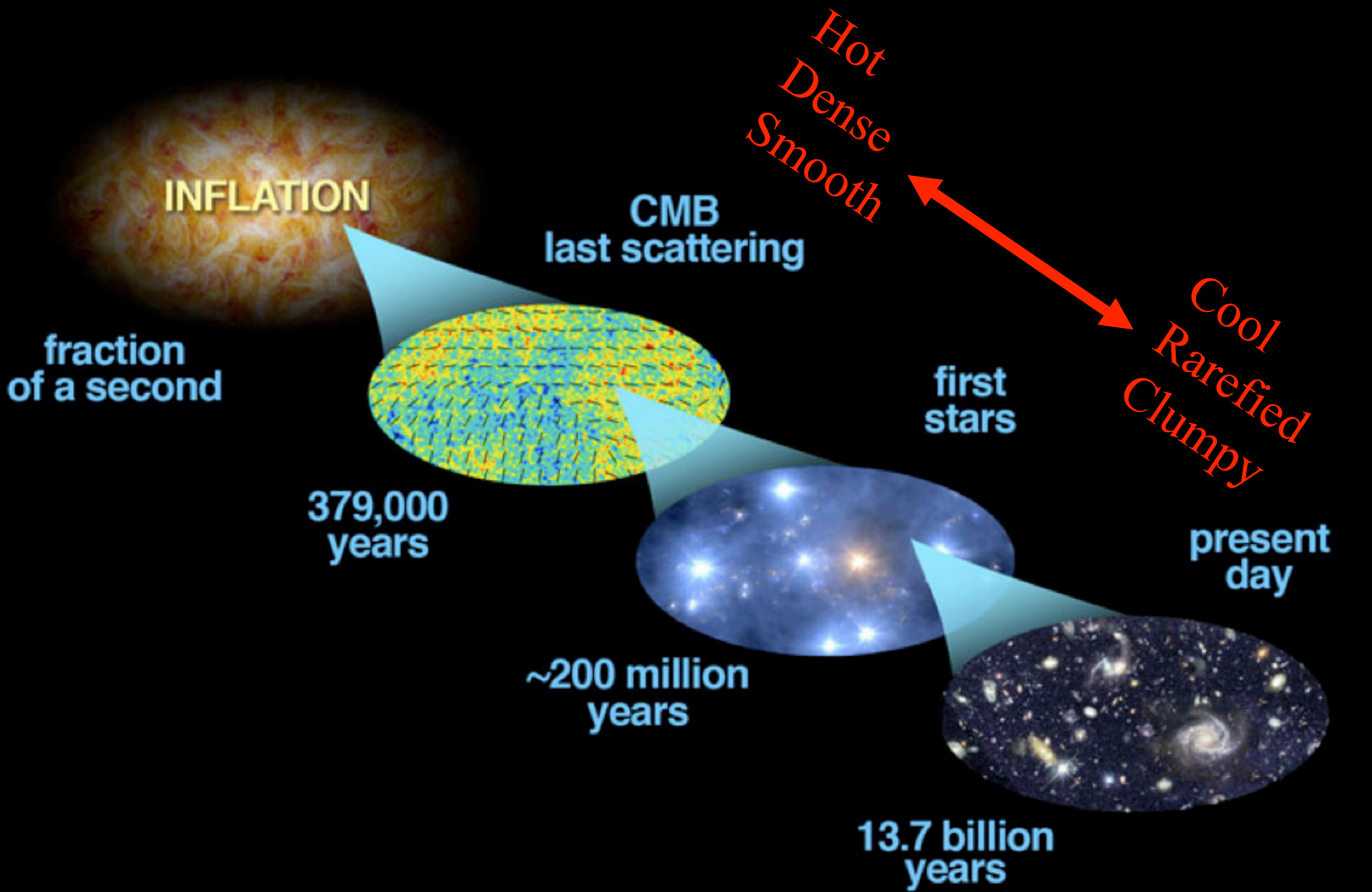
Active Galactic Nuclei as seen by Planck

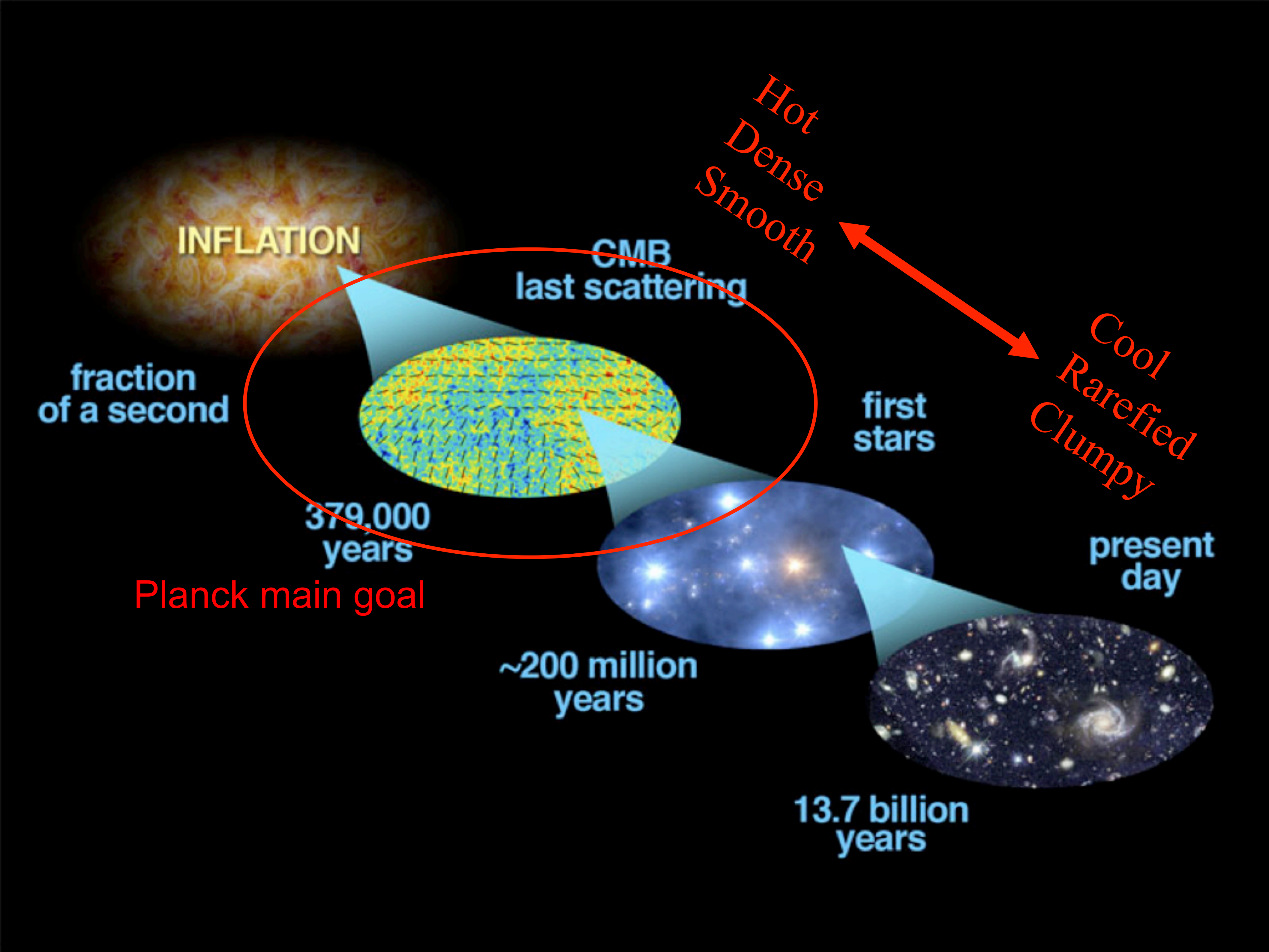
Gianluca Polenta

ASI Science Data Center





Hot
Dense
Smooth
INFLATION
CMB
last scattering
Cool
Rarefied
Clumpy
fraction
of a second
first
stars
379,000
years
present
day
~200 million
years
13.7 billion
years


Hot
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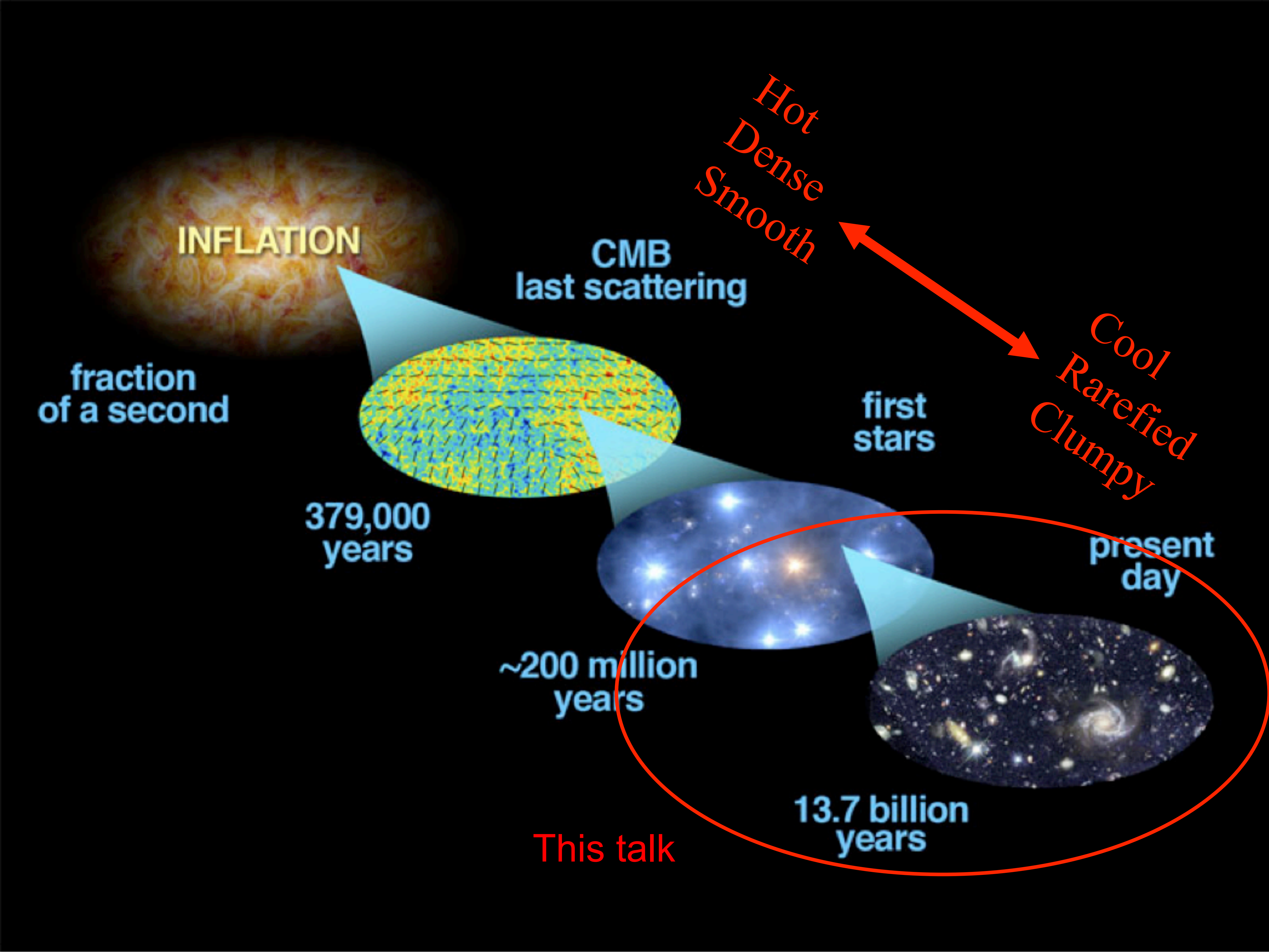


INFLATION
fraction of a second
CMB last scattering
379,000 years
first stars
~200 million years
present day
13.7 billion years
Hot Dense Smooth
Cool Rarefied Clumpy
This talk

Planck basic features

Third generation of CMB experiments.

Wide frequency coverage to distinguish CMB from foreground emissions:

- LFI from 30 to 70 GHz, 12 radiometers
- HFI from 100 to 857 GHz, 52 bolometers

High angular resolution, about few arcmin

Extreme sensitivity for both temperature and polarisation

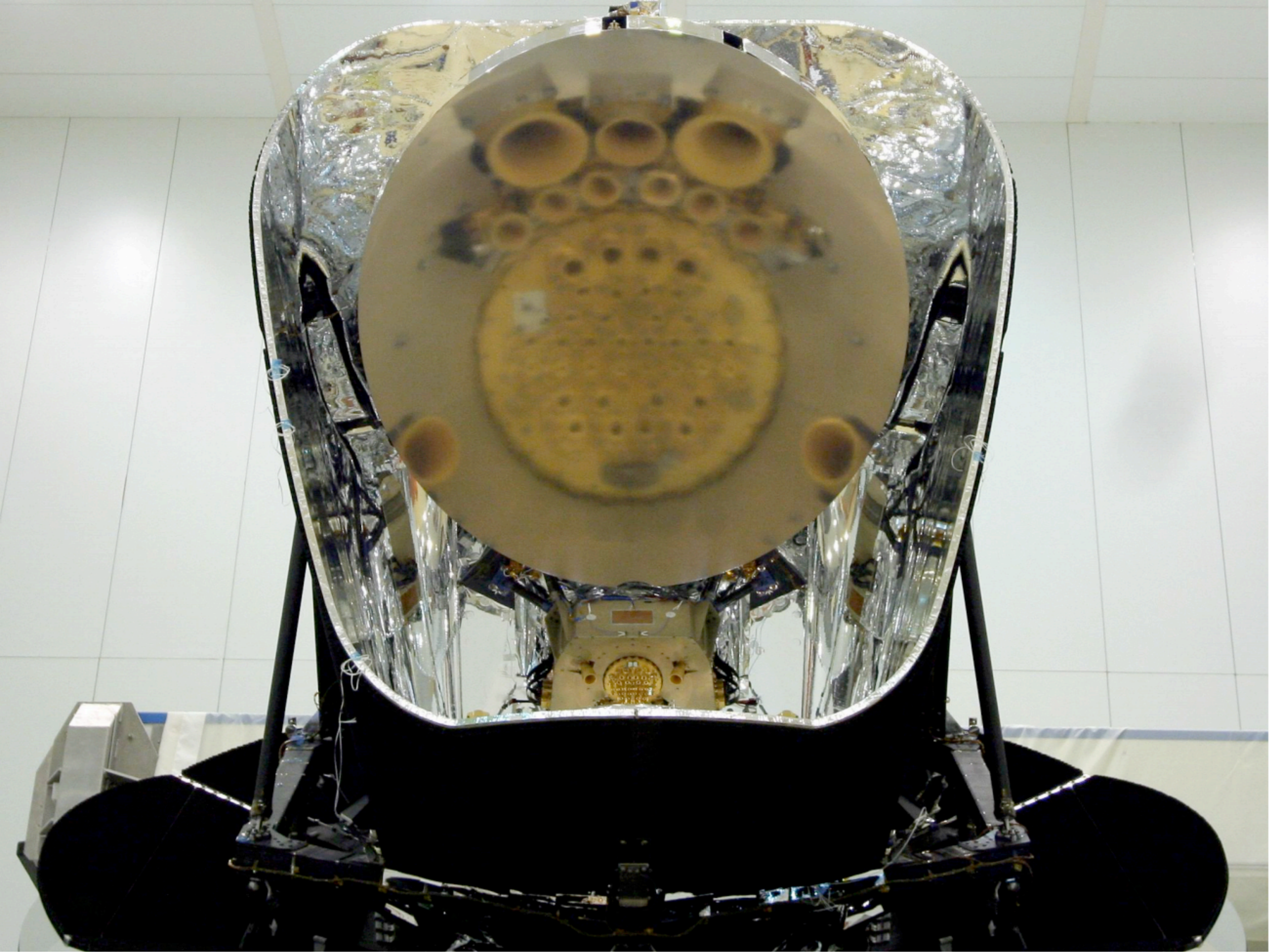
L2 orbit provides stable conditions throughout the mission

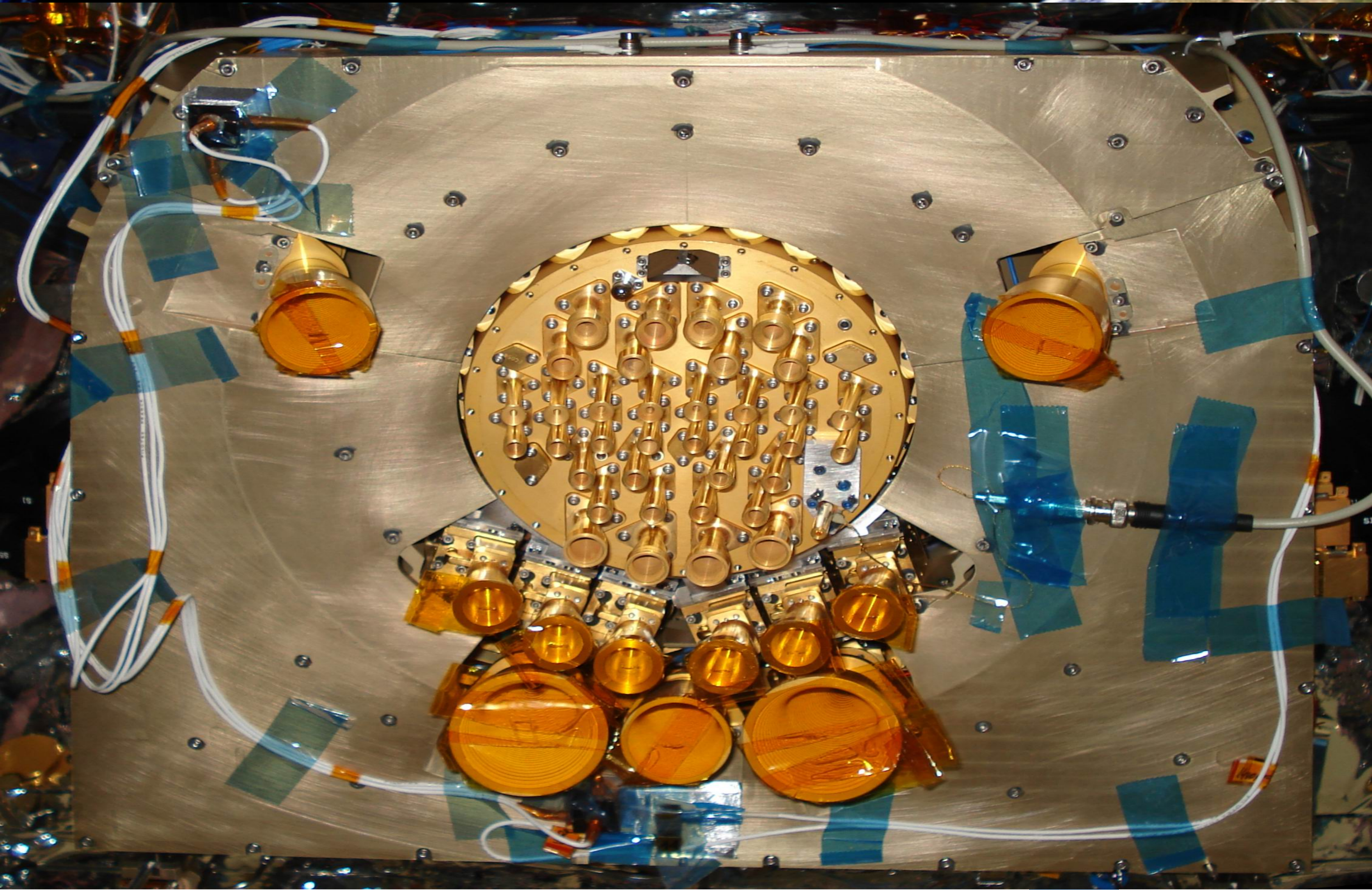
Full sky coverage in ~6 months of observations

Launched on May 14th, 2009, Planck has collected 29 months of data with both instruments

HFI ended its operations last January

LFI is still active: 42 months (7 all sky surveys) of observations already carried out, and will complete 8 all sky surveys





Planck performance summary

channel	$N_{detectors}$ [a]	ν_{center} [b] [GHz]	mean beam[c] FWHM	ellipticity	White-noise[d] sensitivity [μK_{RJ} $s^{1/2}$]	[μK_{CMB} $s^{1/2}$]	calibration[e] uncertainty [%]	faintest source[f] in ERCSC $\|b\| > 30°$ [mJy]
30 GHz	4	28.5	32.65	1.38	143.4	146.8	1	480
44 GHz	6	44.1	27.92	1.26	164.7	173.1	1	585
70 GHz	12	70.3	13.01	1.27	134.7	152.6	1	481
100 GHz	8	100	9.37	1.18	17.3	22.6	2	344
143 GHz	11	143	7.04	1.03	8.6	14.5	2	206
217 GHz	12	217	4.68	1.14	6.8	20.6	2	183
353 GHz	12	353	4.43	1.09	5.5	77.3	2	198
545 GHz	3	545	3.80	1.25	4.9	...	7	381
857 GHz	3	857	3.67	1.03	2.1	...	7	655

The Planck Collaboration, A&A 536, A1, 2011

Planck performance summary

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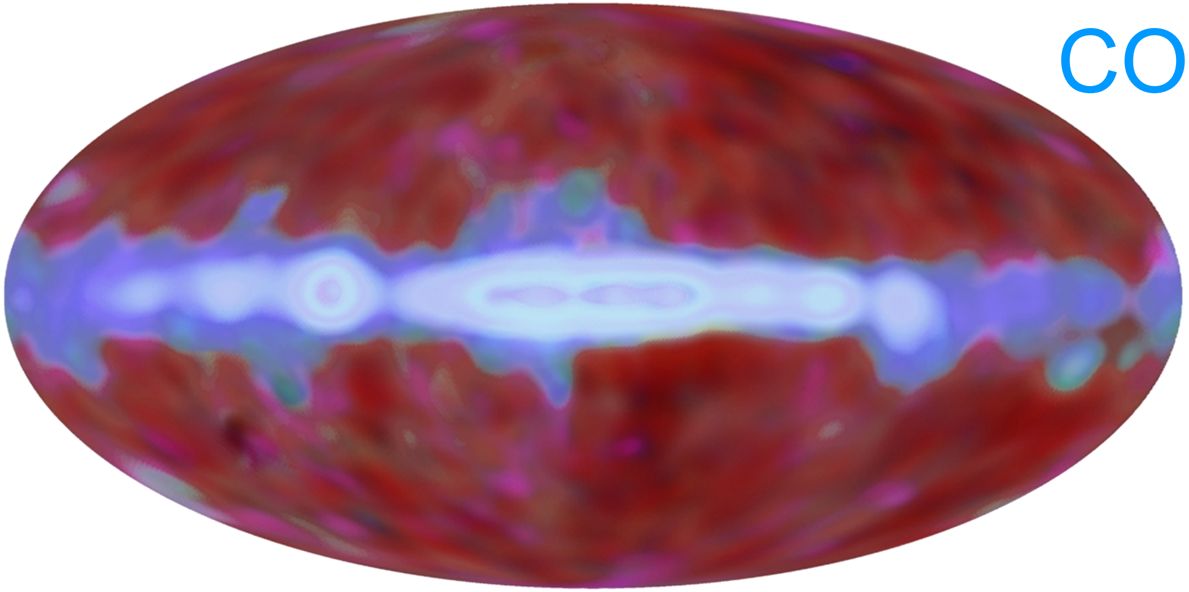
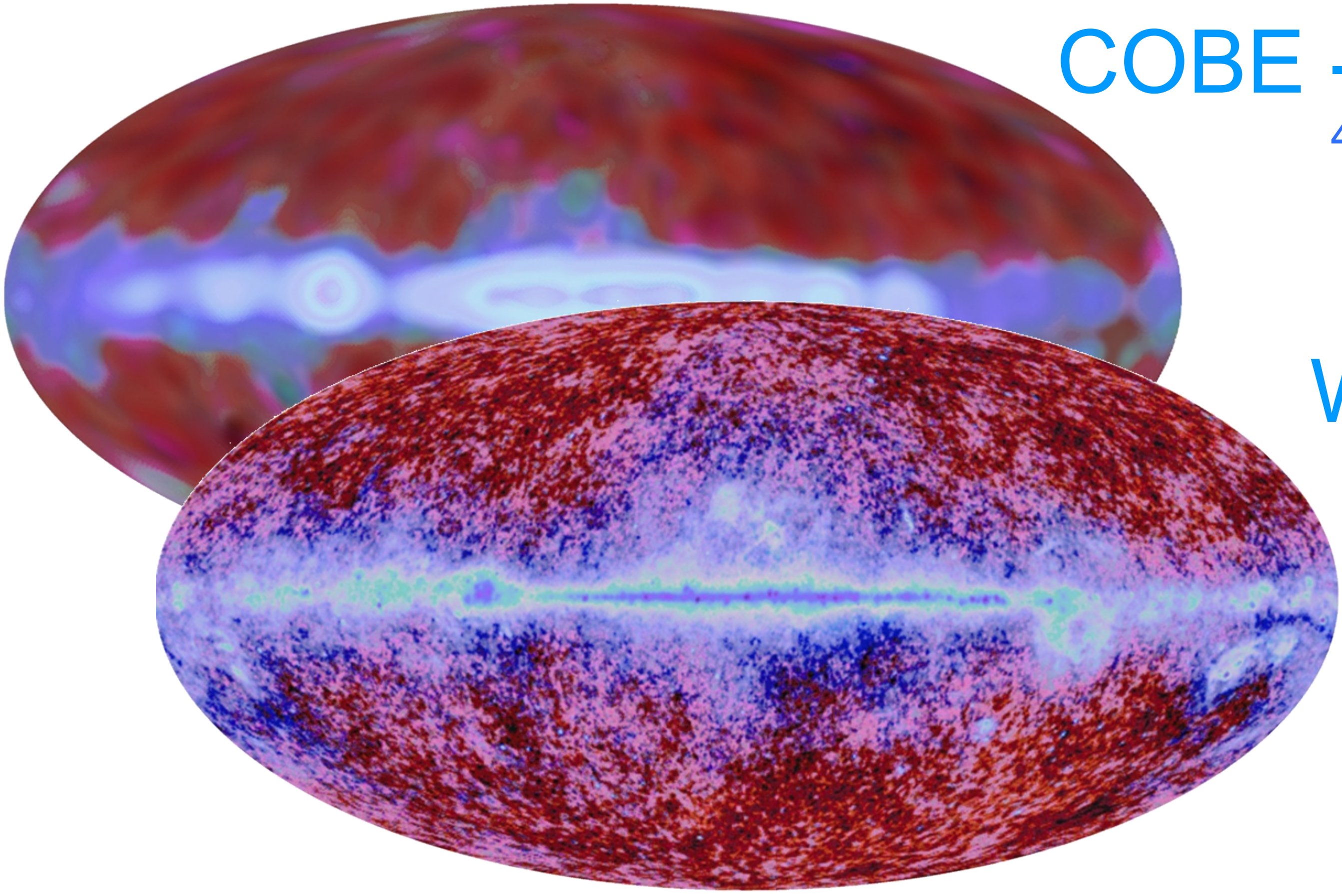
The Planck Collaboration, A&A 536, A1, 2011

COBE - 1989

4-years data



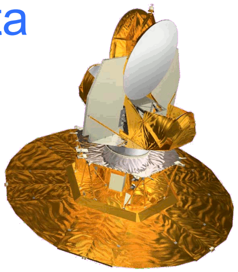


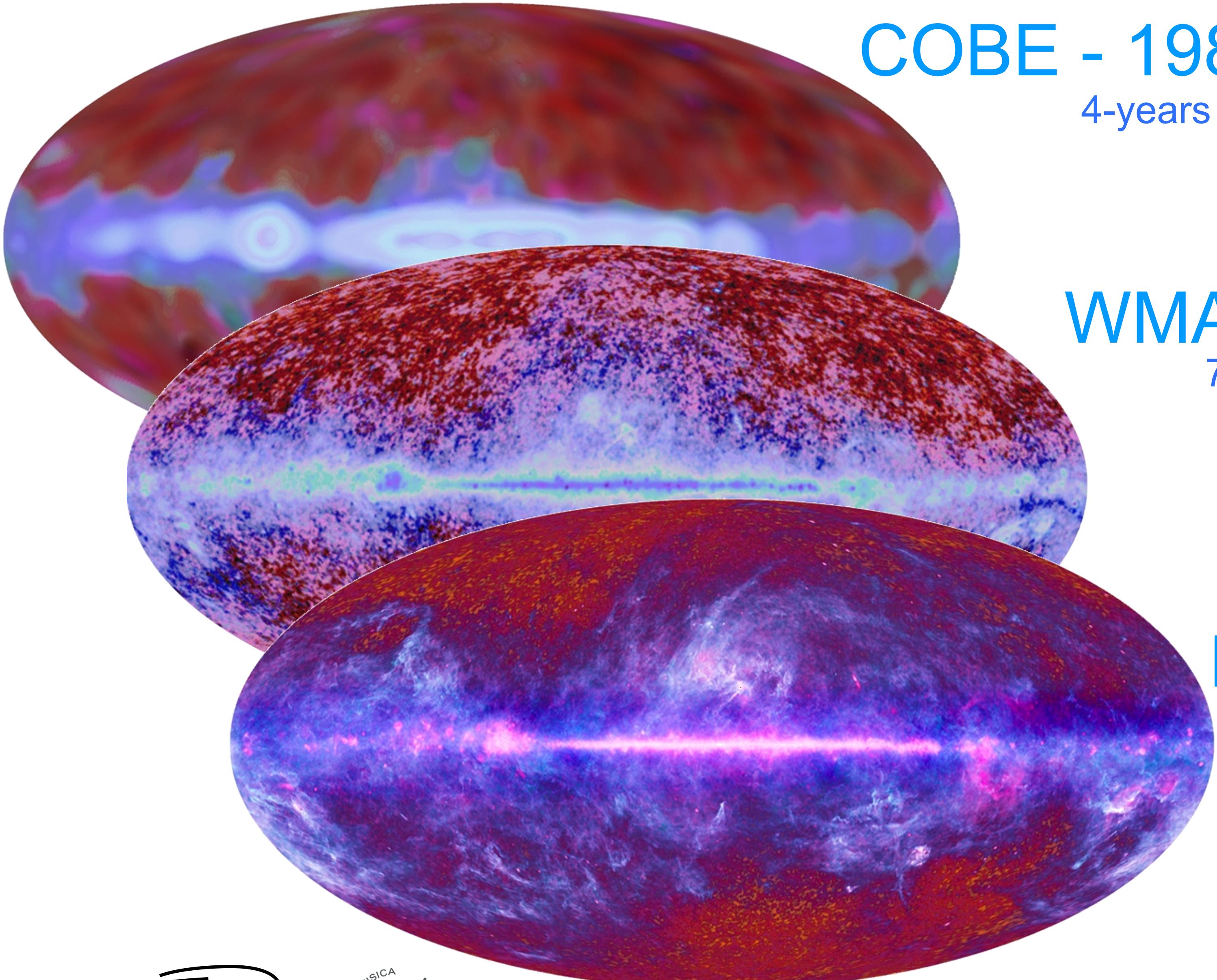
COBE - 1989

4-years data

WMAP - 2001

7-years data



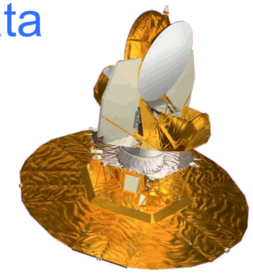


COBE - 1989

4-years data

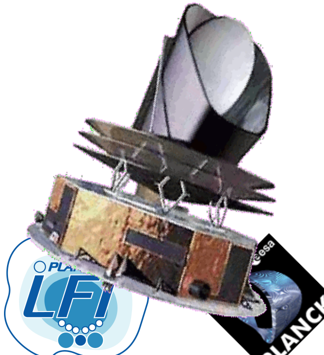
WMAP - 2001

7-years data



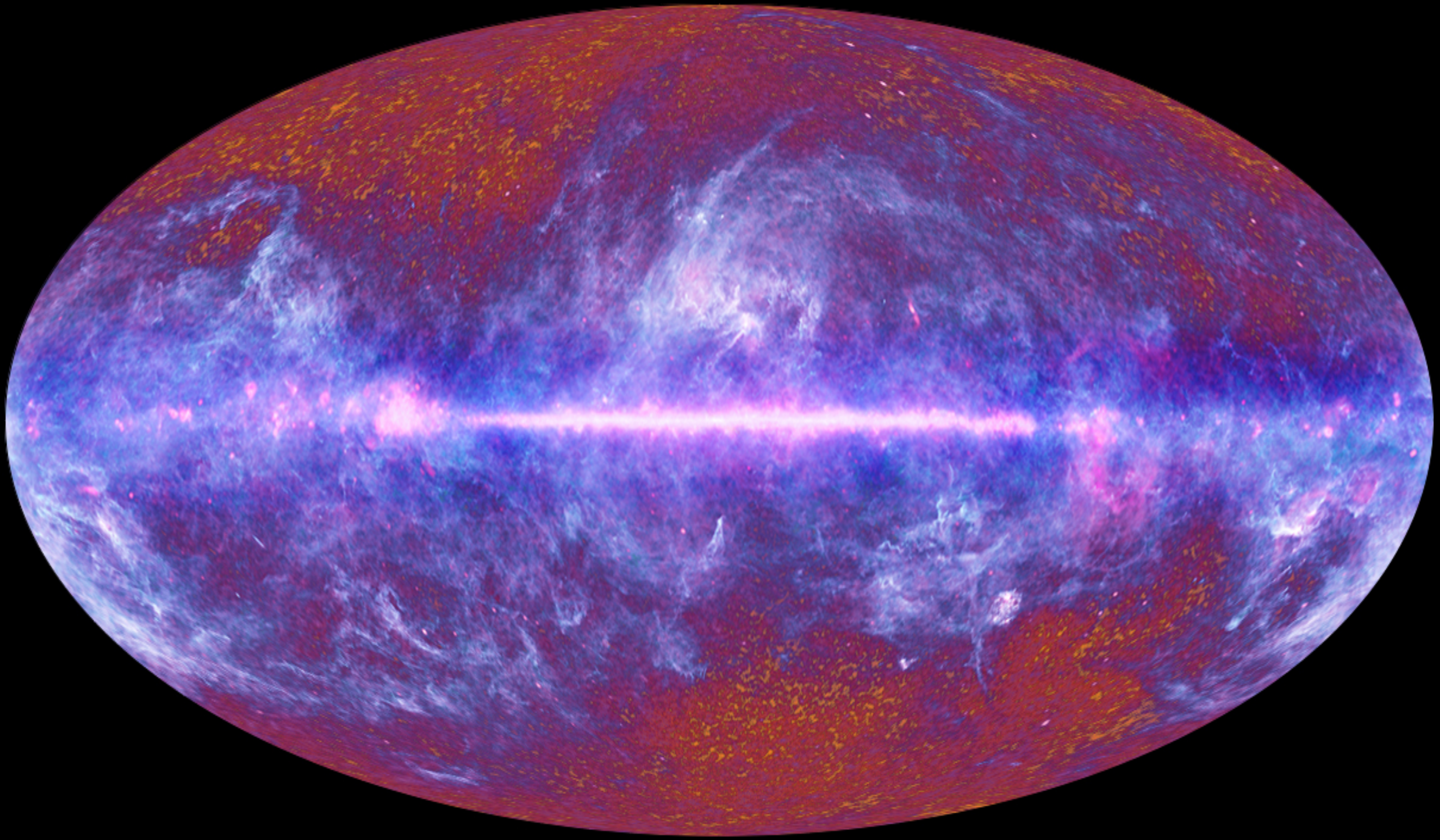
Planck - 2009

6-months data



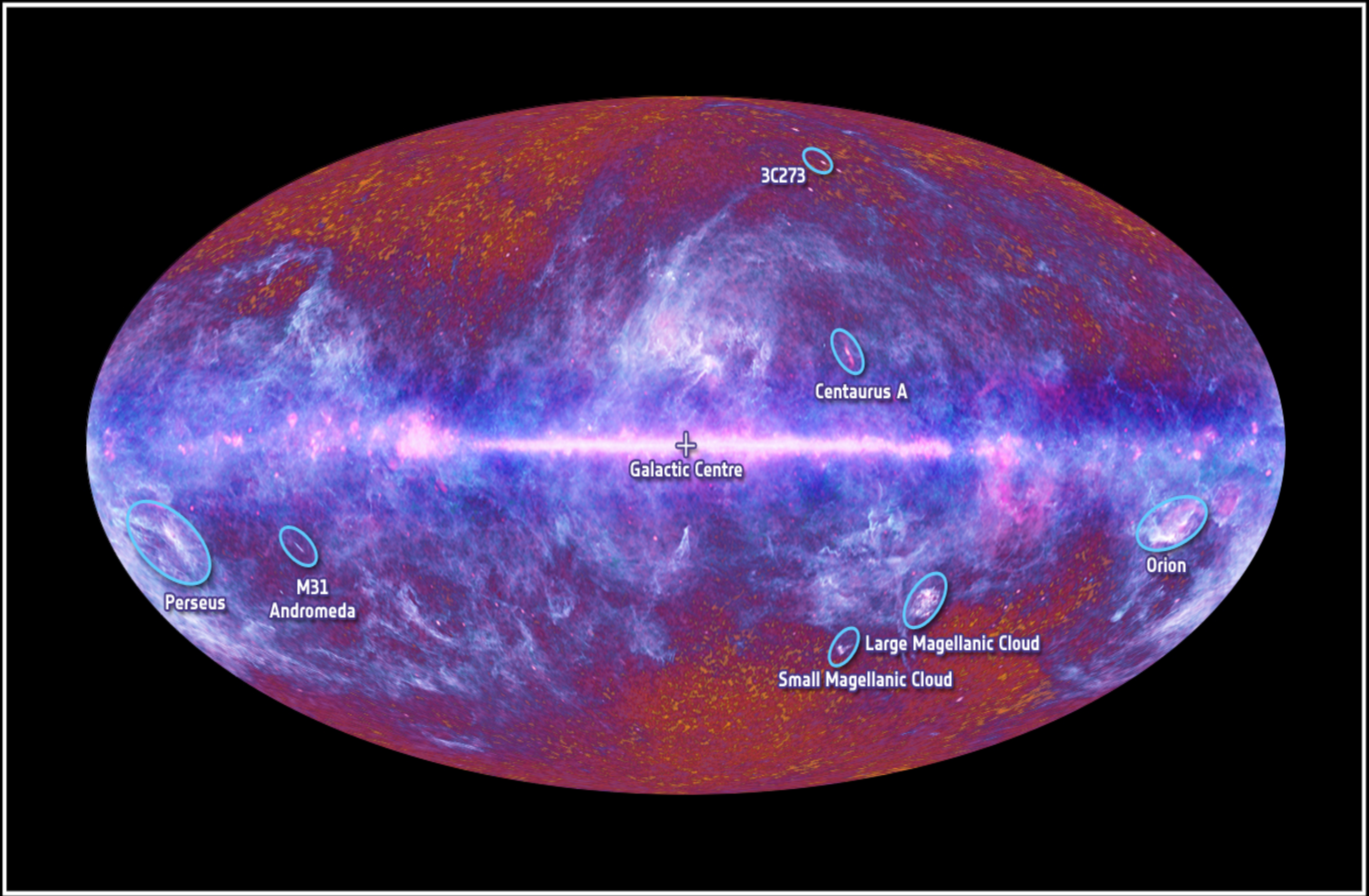
Planck schedule and scientific programme

- January 2011: Early Release Compact Source Catalogue which includes 9 single frequency source catalogues, galaxy cluster catalogue, cold clump catalogue
- A set of 26 papers (A&A special issue 536, 2011) have been published concerning mission status, instrument performance, data processing, ERCSC production, early scientific results on clusters of galaxies (also XMM follow up), galactic and extra-galactic sources, diffuse Galactic emission, CIB, Cold Clumpss, molecular clouds.
- A joint Planck-Swift-Fermi paper on simultaneous observations of blazars led by ASDC (Giommi, et al, 2012, A&A, 541, A160)
- Throughout 2012, Intermediate papers on clusters of galaxies (9 papers), extra-galactic sources (1), Galactic Microwave Haze (1), and diffuse Galactic emission (1)
- March 2013: first data release including all-sky maps from the nominal mission (15 months) and first cosmology results, 47th ESLAB symposium, 2-5 April 2013, ESTEC
- Early 2014: second data release including data and results from the extended mission



The Planck one-year all-sky survey

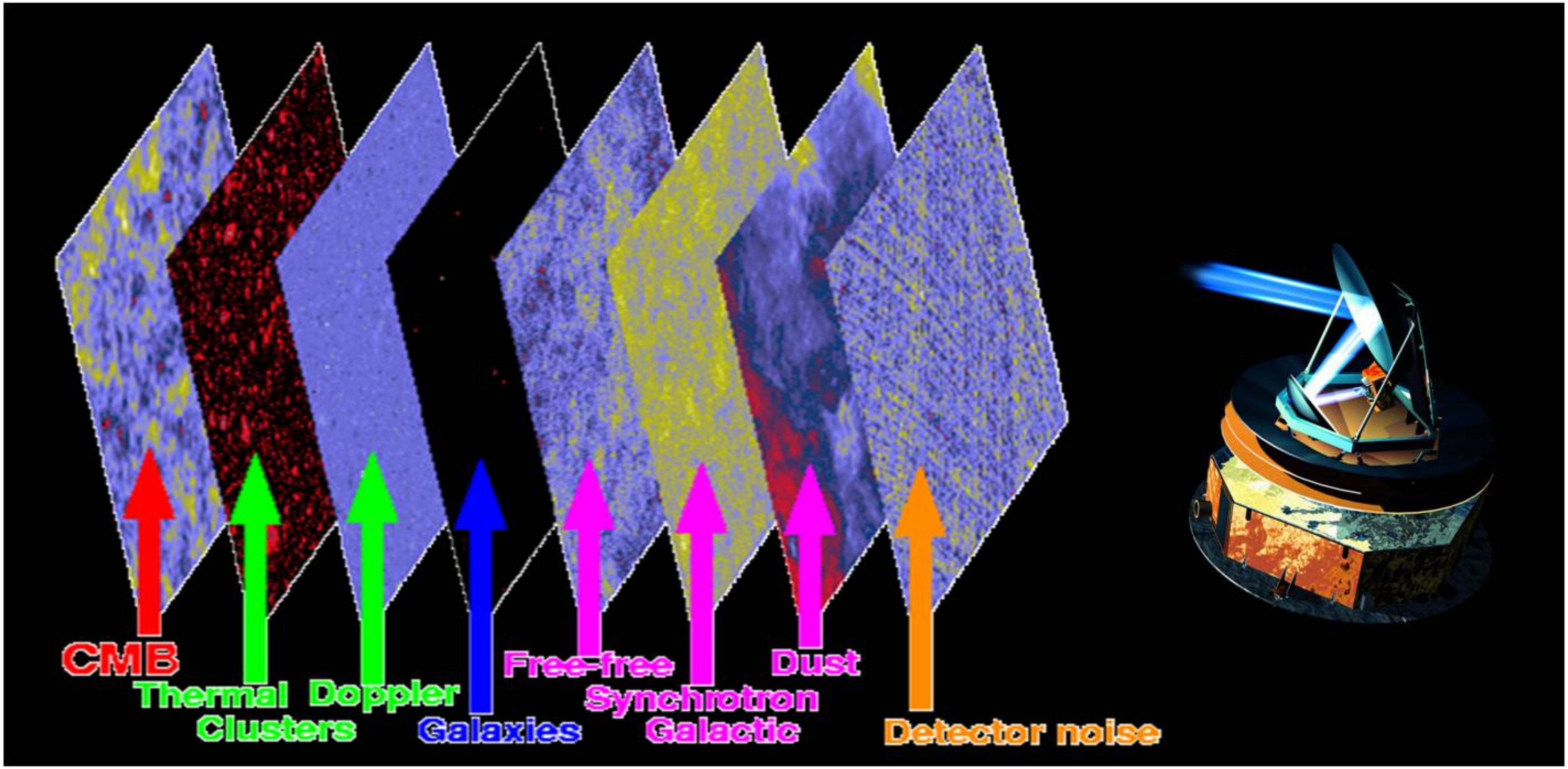
esa



The Planck one-year all-sky survey

Frequency coverage

The microwave emission seen by Planck is the sum of several components

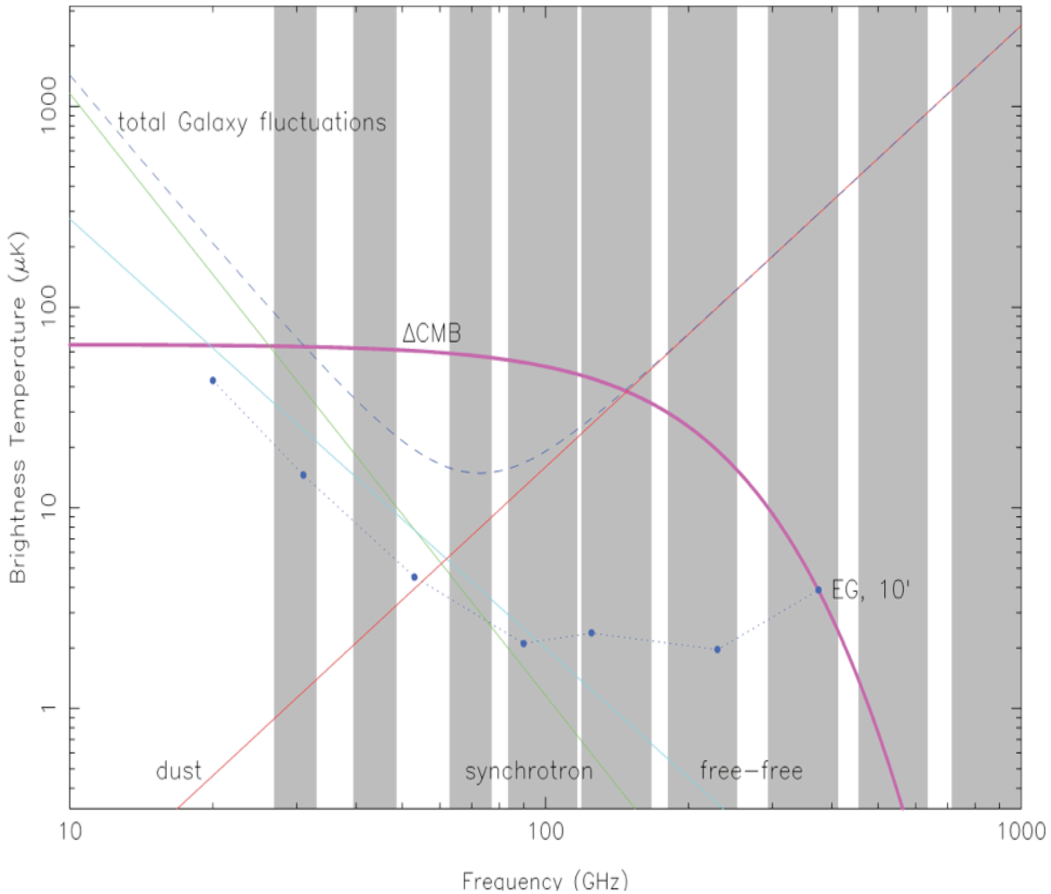


Frequency coverage

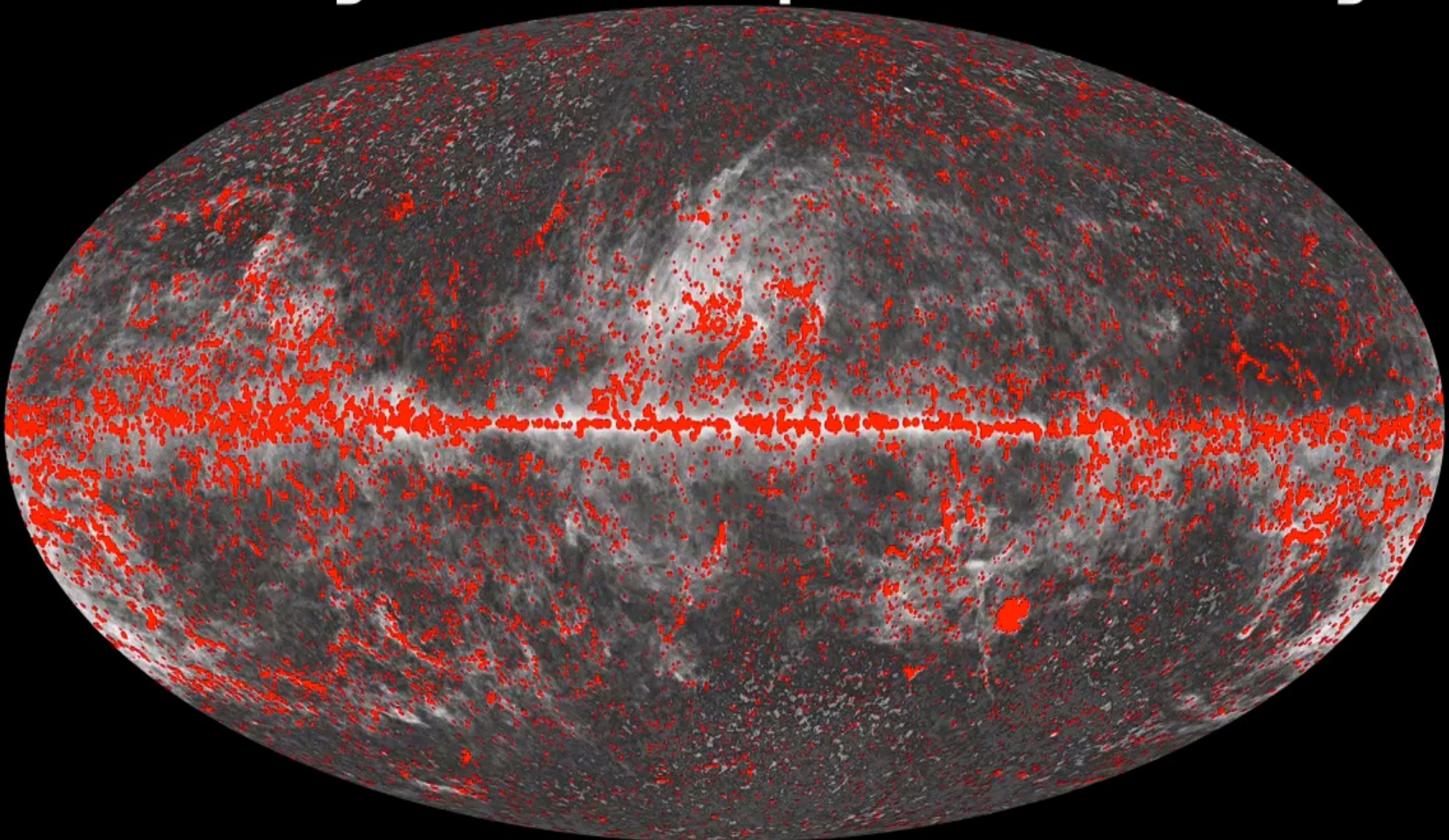
Different sources have different spectral behaviour:

- CMB
- Diffuse synchrotron emission from the Milky Way
- Free-free
- Interstellar dust
- Extragalactic sources
- Clusters of galaxies

Planck frequency bands cover a broad range around the peak of CMB spectrum, allowing for a good separation of CMB signal from foreground emissions.



Planck Early Release Compact Source Catalogue



All compact sources

The Planck one-year all-sky survey

The Planck Early Release Compact Source Catalogue

The Planck Collaboration, A&A, 536:A7, 2011

Released on Jan 2011, includes 10 months of data, from Aug 2009 to June 2010, i.e. one complete sky survey + 60% of the second survey

Nine catalogues, one for each Planck band, for a total of ~15000 sources

Only high significance detections: based on 10σ flux density limit with also some fainter sources at high galactic latitude

Reliability > 90% from MC analysis

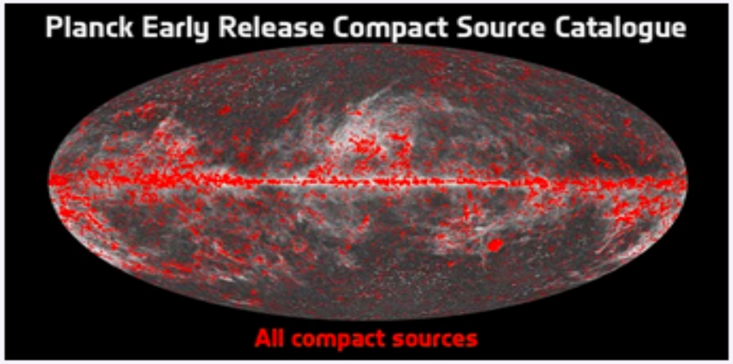
Freq [GHz]	30	44	70	100	143	217	353	545	857
λ [μm]	10000	6818	4286	3000	2098	1382	850	550	350
Sky coverage in %	99.96	99.98	99.99	99.97	99.82	99.88	99.88	99.80	99.79
Beam FWHM [arcmin][a]	32.65	27.00	13.01	9.94	7.04	4.66	4.41	4.47	4.23
# of sources	705	452	599	1381	1764	5470	6984	7223	8988
# of $\|b\| > 30^\circ$ sources	307	143	157	332	420	691	1123	2535	4513
10σ[b] [mJy]	1173	2286	2250	1061	750	807	1613	2074	2961
10σ[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

ERCSC is available from ESA Planck Legacy Archive, IPAC website, IA2 (VO), and ASDC interactive version http://www.asdc.asi.it/planck/ERCSC/

The Planck ERCSC

@ ASDC v1.0

Help
Show/hide columns
Advanced filtering
Print current view of table
Print complete table
Reset all filters



30GHz | 44GHz | 70GHz | 100GHz | 143GHz | 217GHz | 353GHz | 545GHz | 857GHz

VO Tools

VO mode: off (turn on)
Help

Cone Search
Source Name
Resolve name
RA, Dec / L,B Clean
(e.g. 00 02 34.6,-53 01 10.2 or 0.64417,-53.0195)
radius 5 arcmin Search
Reset filter

This is an interactive version of the Planck Early Release Compact Source Catalogue released by ESA on January 11th, 2011.

The same catalogue is available from both ESA and IPAC website, and VO access is available from IA2.

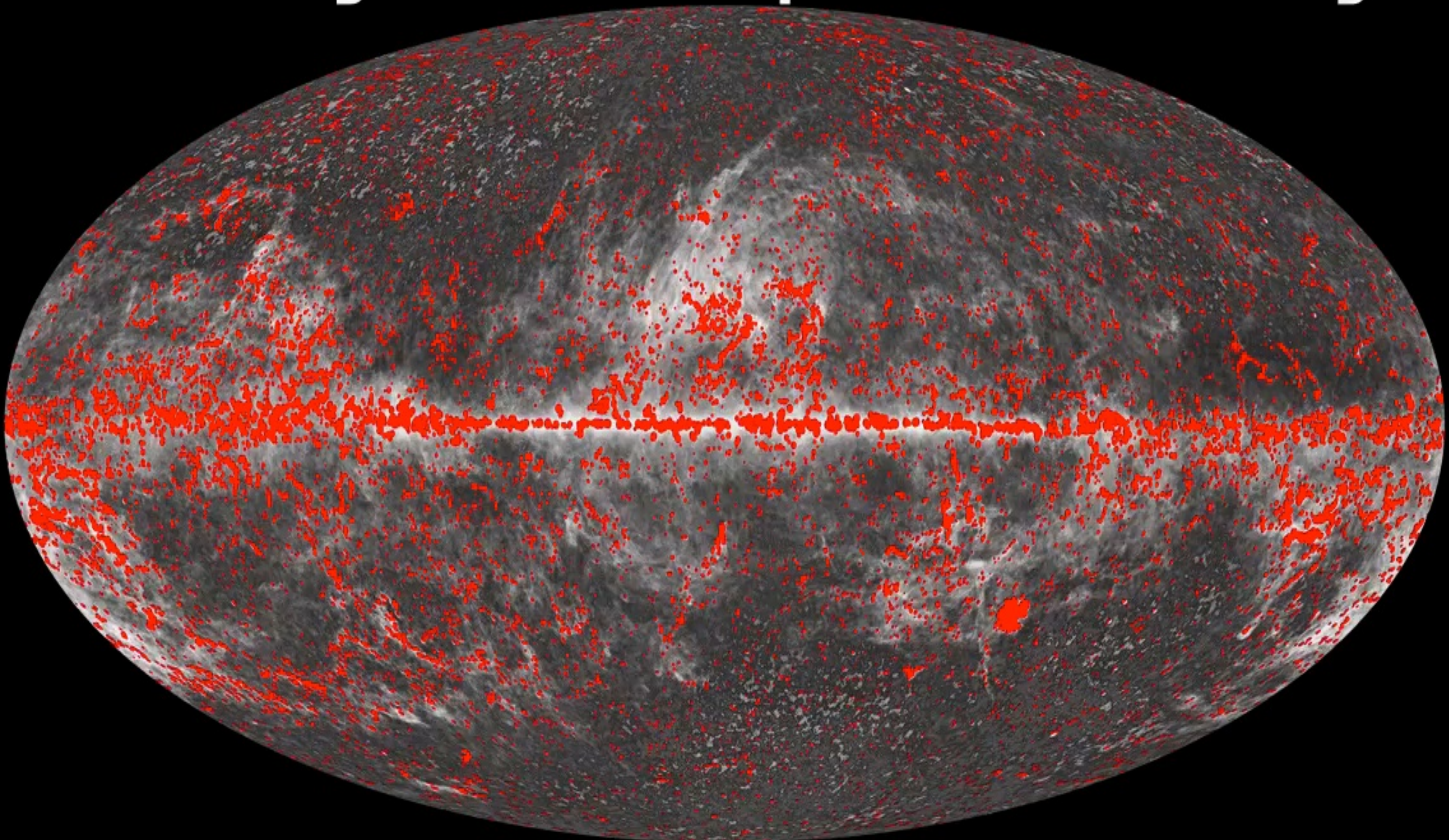
A general description of the ERCSC is available from The Planck Collaboration, 2011, while more details can be found in the Explanatory Supplement

Export Current view of Table in: Latex format | FITS format | Raw text format | CSV text format

Previous Page | Next Page | Page Size (# of lines) 50 | Refresh page | Reset all filters | Show all entries

Entry number (Selection mode: Include, All)		Source name	RA (J2000.0) hh mm ss.d	Dec (J2000.0) dd mm ss.d	LII (deg)	BII (deg)	flux density +/- err (mJy)
1 Select	ASDC Data Explorer	PLCKERC030 G118.11+04.94	00 01 17.0	+67 20 35.0	118.1171	4.94142	5.3e+4+/-839
2 Select	ASDC Data Explorer	PLCKERC030 G117.62+02.22	00 01 44.5	+64 34 50.9	117.62942	2.22199	1776.4+/-138
3 Select	ASDC Data Explorer	PLCKERC030 G084.65-71.12	00 04 10.9	-11 51 28.0	84.6562	-71.12824	719.5+/-119
4 Select	ASDC Data Explorer	PLCKERC030 G093.49-66.62	00 06 11.2	-06 22 33.9	93.49979	-66.6266	1514.1+/-82

Planck Early Release Compact Source Catalogue

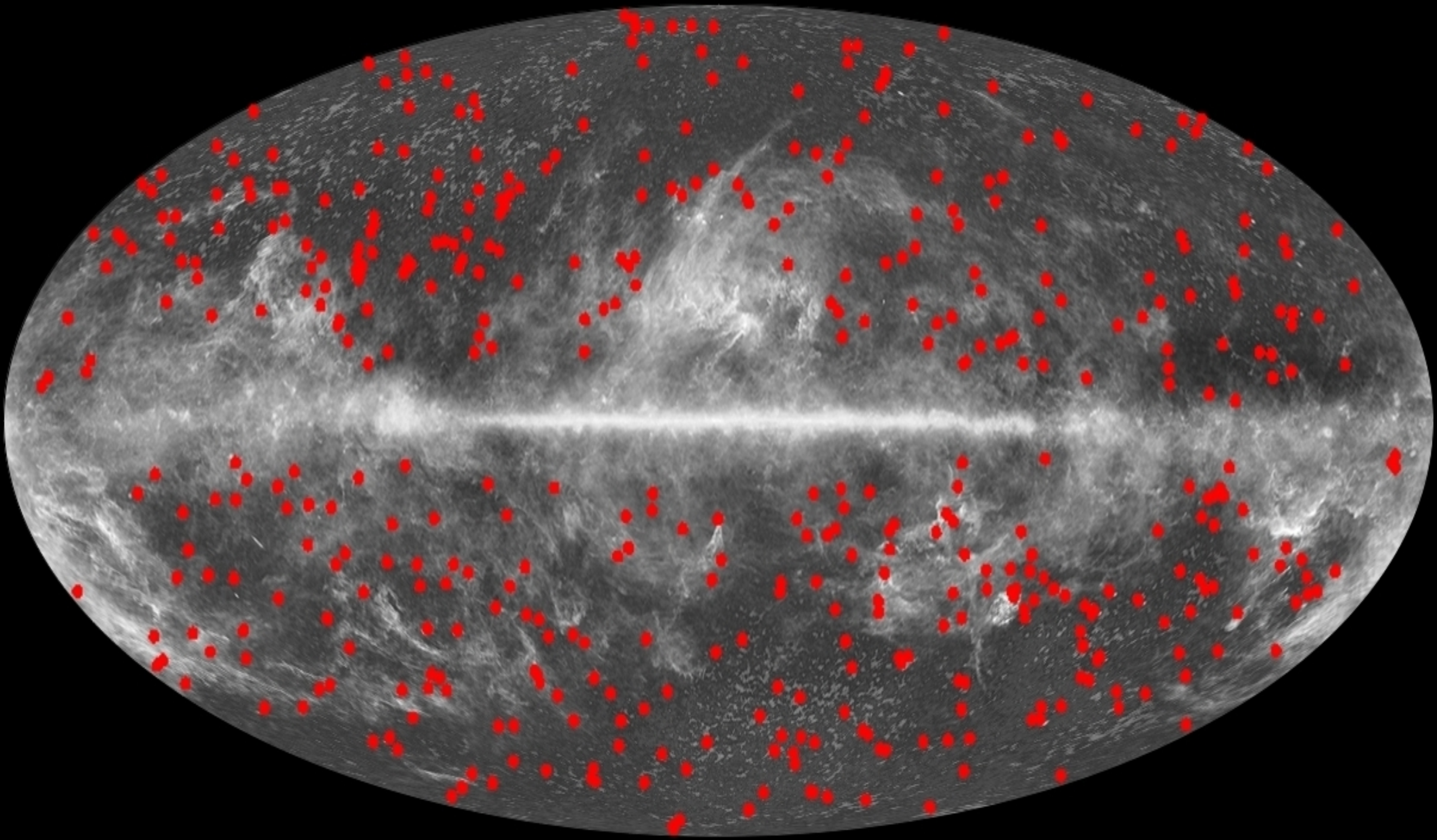


All compact sources

The Planck one-year all-sky survey

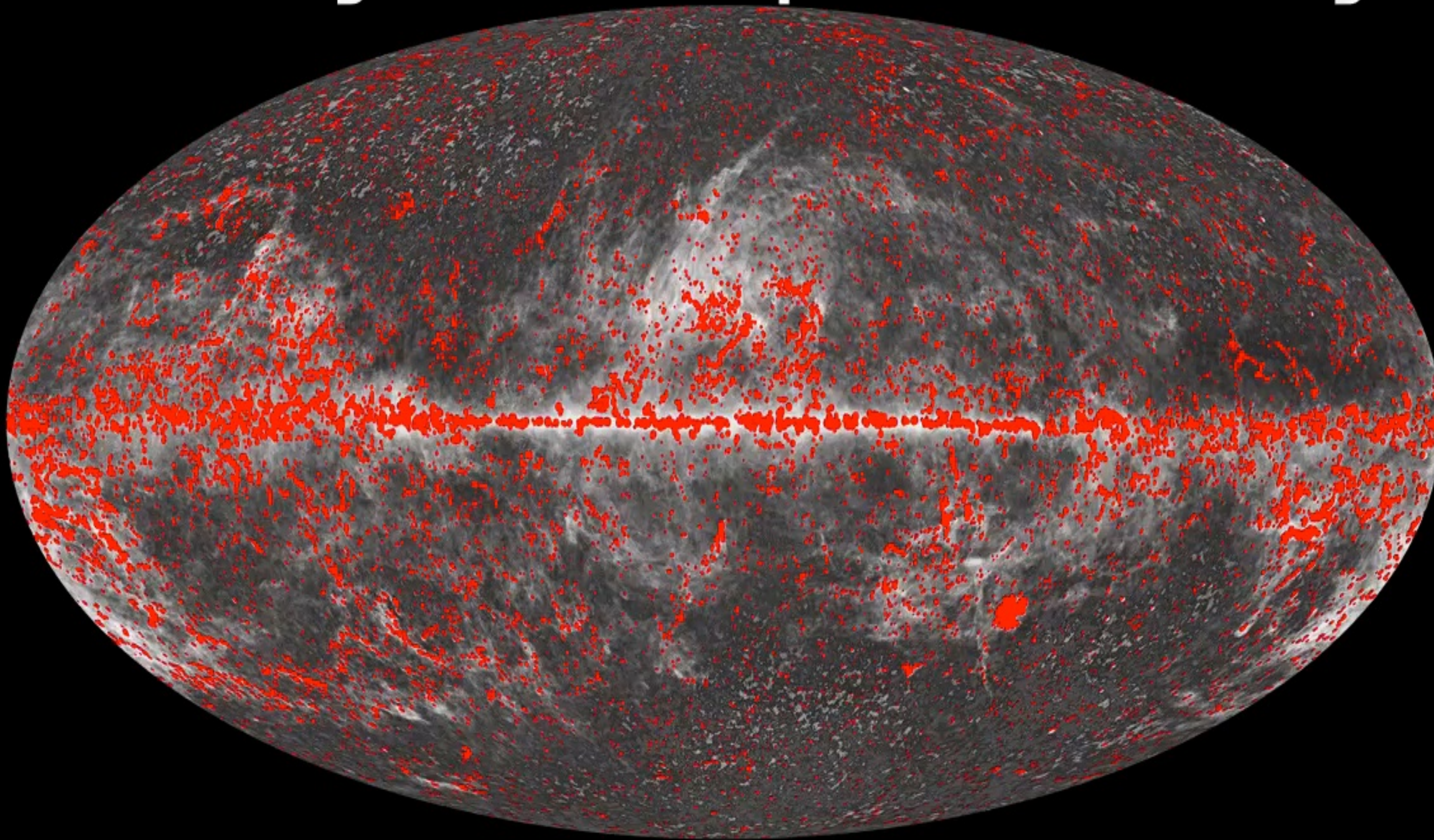
esa

WMAP 7Year Point Source Catalogue



Overlapped to the Planck one-year all-sky map

Planck Early Release Compact Source Catalogue



All compact sources

The Planck one-year all-sky survey

ERCSC: two populations of extragalactic sources

For each source we have fitted a single power law $S_\nu \propto \nu^\alpha$ using only adjacent frequencies.

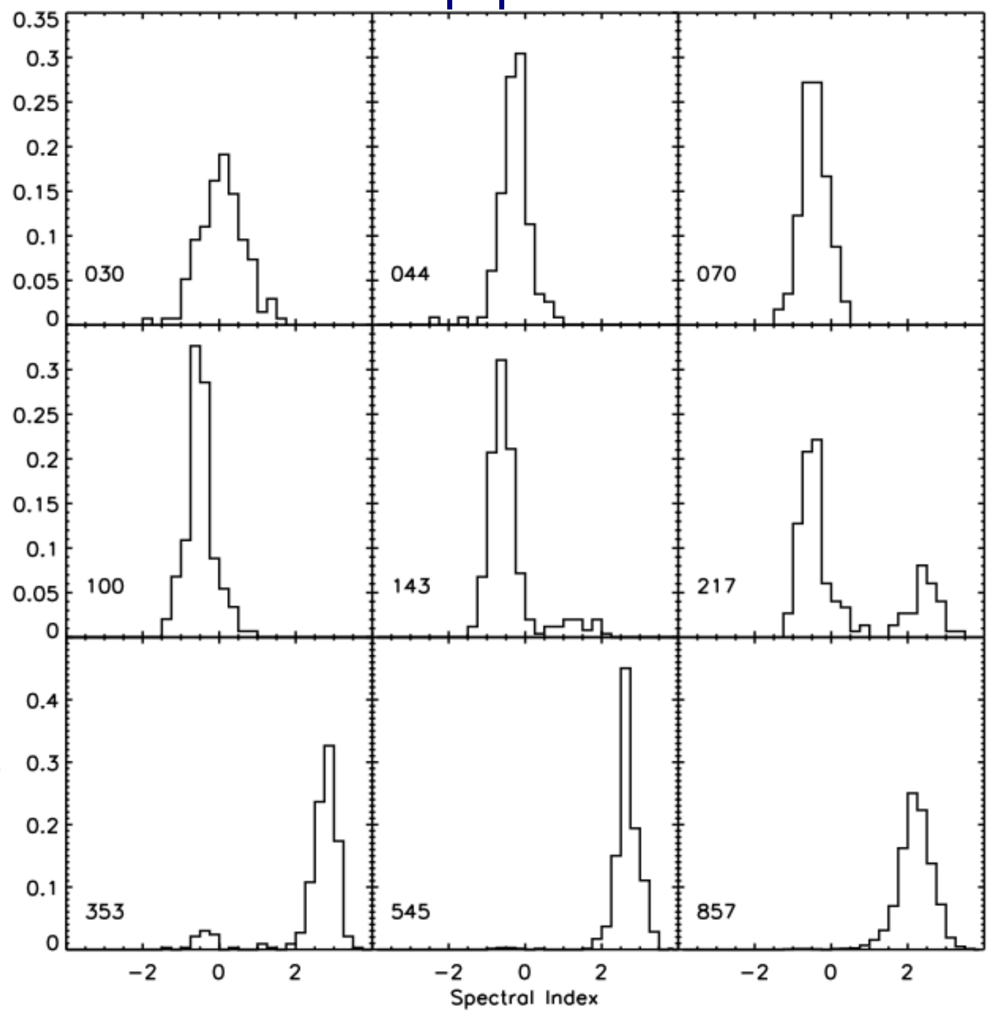
Flat spectrum at 30GHz shifting to -0.5 at 143GHz, consistent with synchrotron emission from radio loud AGN.

At 143 and 217GHz appear also sources with thermal dust emission, that dominate from 353GHz.

Table 2. Median and standard deviations of the spectral index distributions between 30 GHz and the selected frequency.

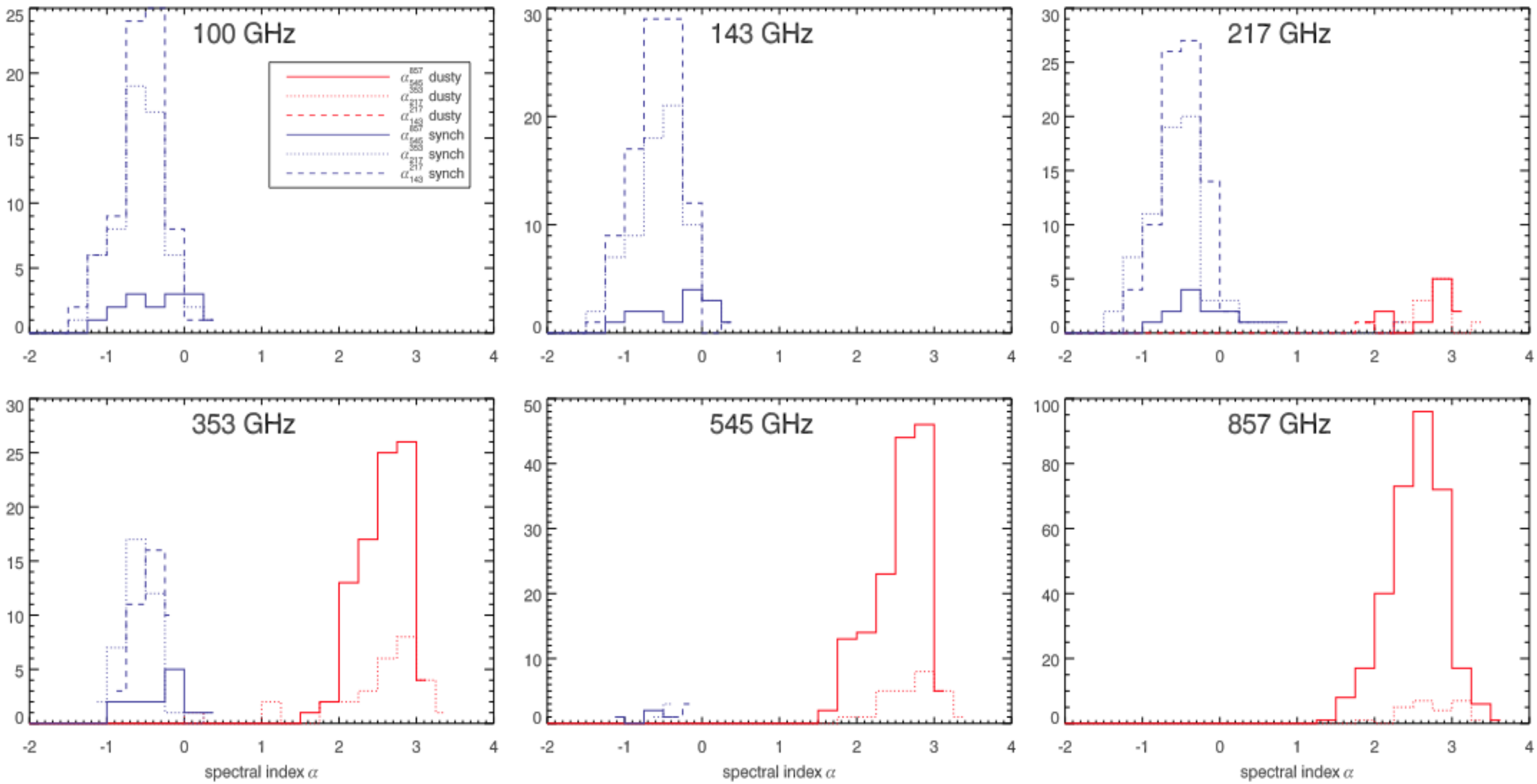
ν[GHz]	44	70	100	143	217
median	−0.06	−0.18	−0.28	−0.39	−0.37
error	0.01	0.01	0.01	0.01	0.01
σ	0.30	0.18	0.17	0.16	0.15

|b|>30°



ERCSC: two populations of extragalactic sources

Updated in A&A, 550:A133, 2013, including sky coverage information and spectral indices from different frequency ranges.

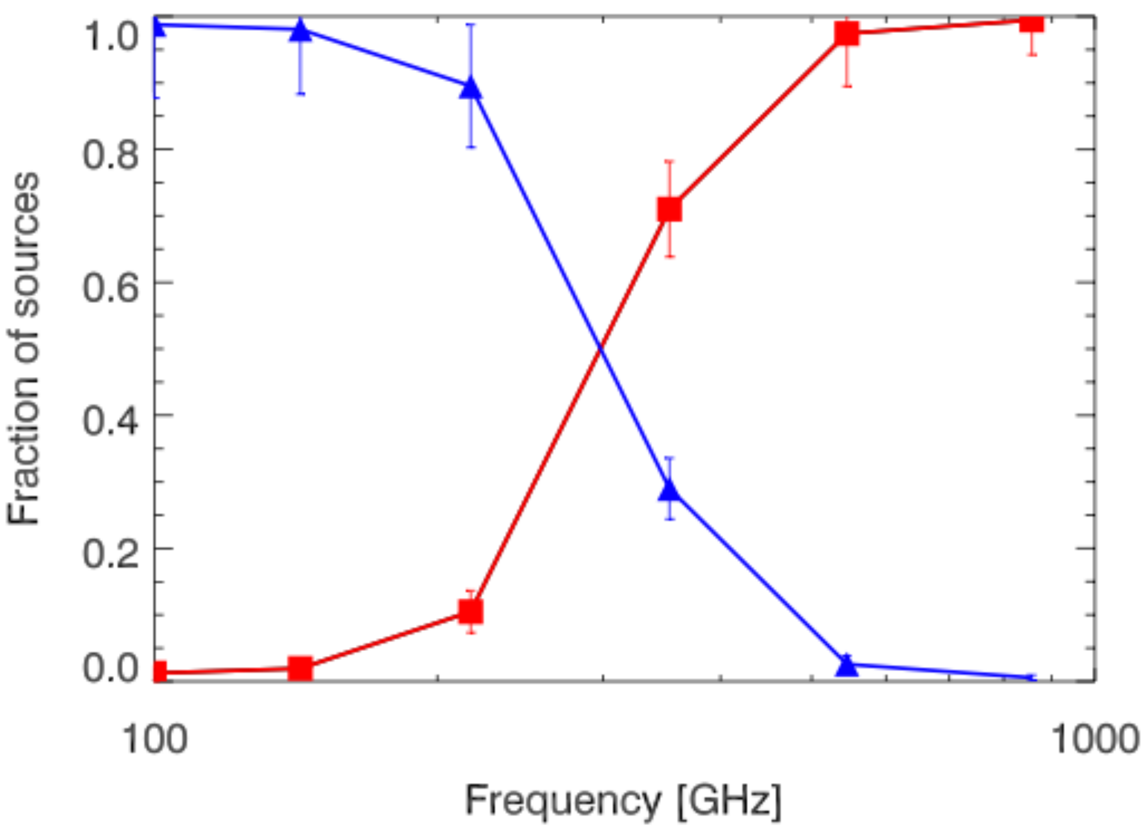


ERCSC: two populations of extragalactic sources

Updated in A&A, 550:A133, 2013, including sky coverage information and spectral indices from different frequency ranges.

For a complete sample, we find the same number of dusty and synchrotron sources at ~300GHz.

The channel at 217GHz is still dominated by sources with synchrotron spectrum.



ERCSC: number counts

The Planck Collaboration, A&A, 536:A13, 2011

Euclidean number counts at 30, 44, and 70GHz.

Red: Planck

Gray squares: WMAP5

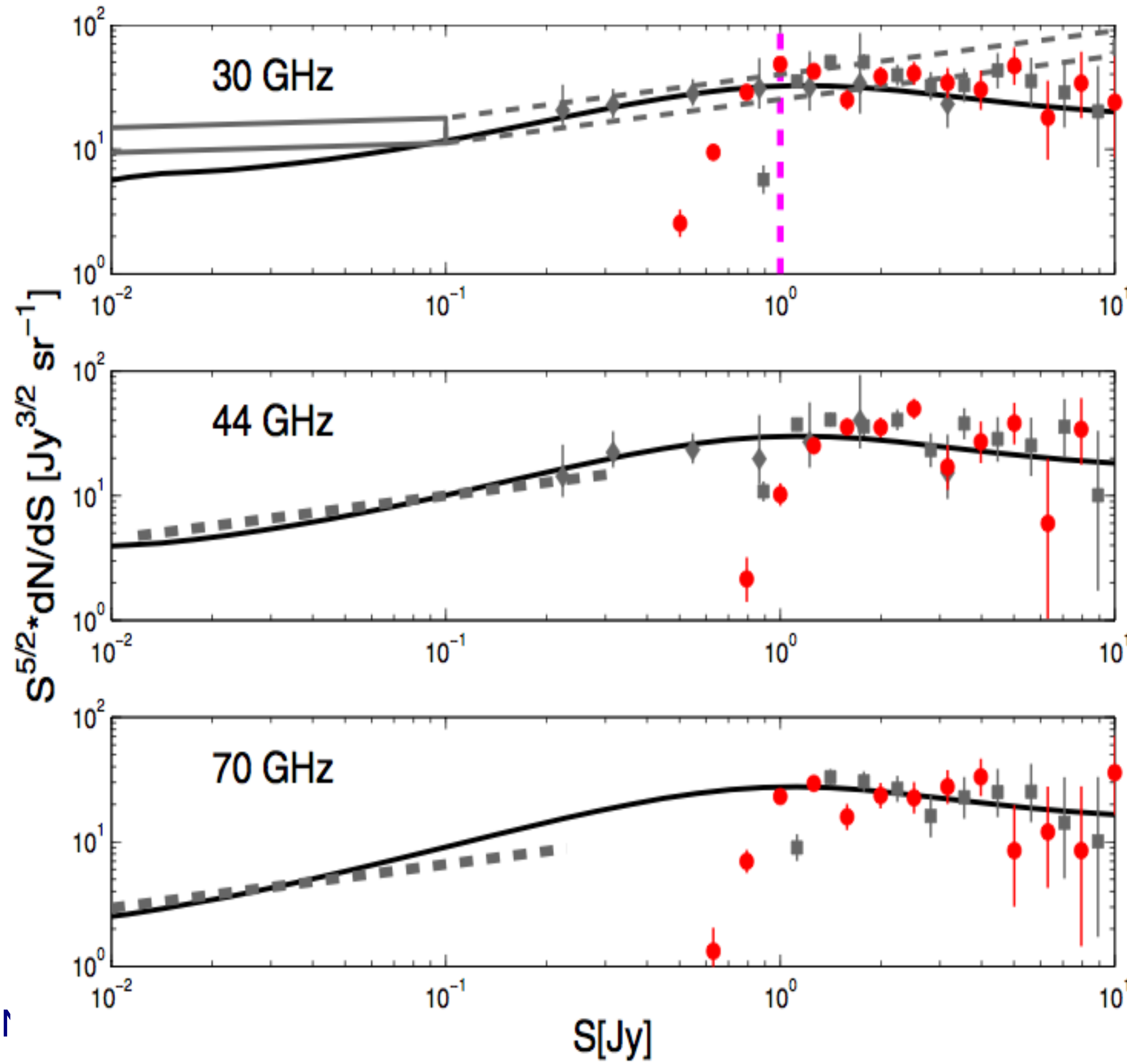
Gray diamonds: PACO

Gray box at 30GHz: DASI

Gray dashed box: VSA

Gray dahsed lines: 15GHz 9C sources extrapolation

Solid black line: De Zotti et al 2005 model



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ERCSC: number counts

The Planck Collaboration, A&A, 536:A13, 2011

Euclidean number counts at 100, 143, and 217GHz.

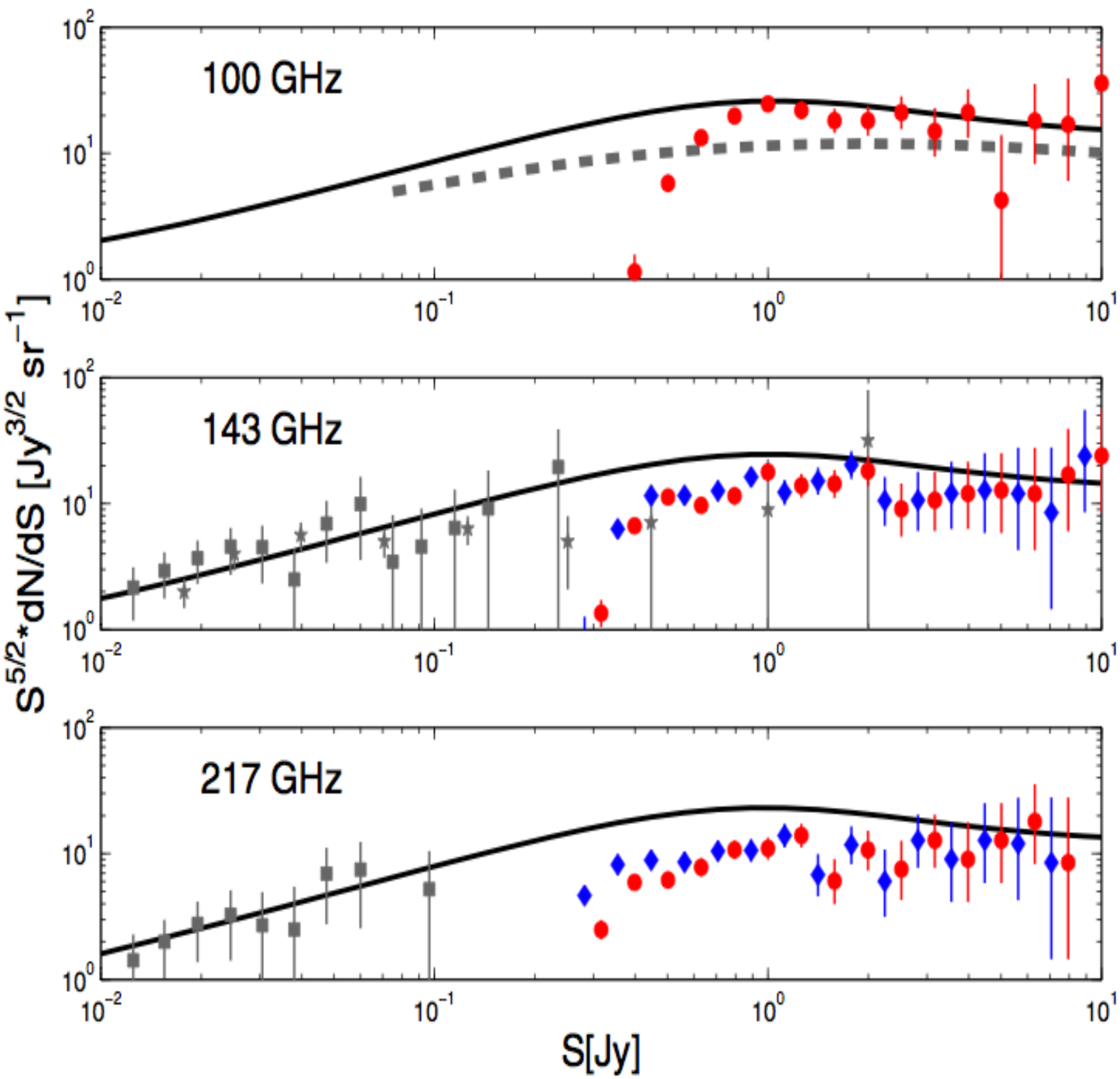
Red: Planck, sources with 30GHz counterpart

Blue: Planck number counts after dusty sources removal

Gray squares: SPT

Gray stars: ACT

Solid black line: De Zotti et al 2005 model overestimates number counts above 100GHz



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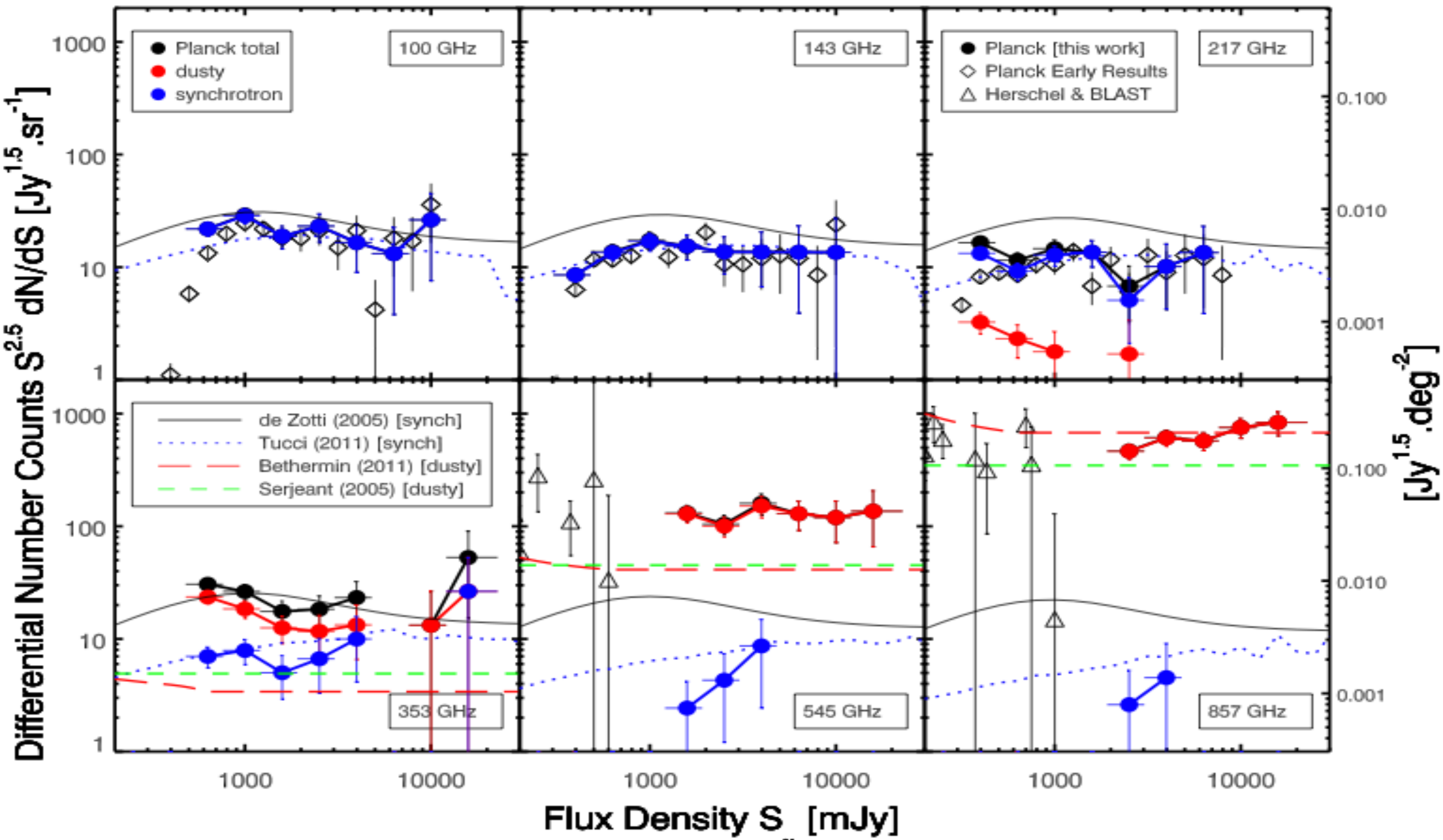
ERCSC: number counts

Updated in A&A, 550:133, 2013, separating dusty and synchrotron sources



A&A 541, A160 (2012)
DOI: 10.1051/0004-6361/201117825

Astronomy & Astrophysics

Simultaneous *Planck*, *Swift*, and *Fermi* observations of X-ray and γ-ray selected blazars

P. Giommi[2,3], G. Polenta[2,23], A. Lähteenmäki[1,19], D. J. Thompson[5], M. Capalbi[2], S. Cutini[2], D. Gasparrini[2], J. González-Nuevo[43], J. León-Tavares[1], M. López-Caniego[32], M. N. Mazziotta[33], C. Monte[14,33], M. Perri[2], S. Rainò[14,33], G. Tosti[35,15], A. Tramacere[28], F. Verrecchia[2], H. D. Aller[4], M. F. Aller[4], E. Angelakis[41], D. Bastieri[13,34], A. Berdyugin[45], A. Bonaldi[37], L. Bonavera[43,7], C. Burigana[26], D. N. Burrows[10], S. Buson[34], E. Cavazzuti[2], G. Chincarini[46], S. Colafrancesco[23], L. Costamante[47], F. Cuttaia[26], F. D'Ammando[27], G. de Zotti[22,43], M. Frailis[24], L. Fuhrmann[41], S. Galeotta[24], F. Gargano[33], N. Gehrels[5], N. Giglietto[14,33], F. Giordano[14], M. Giroletti[25], E. Keihänen[12], O. King[42], T. P. Krichbaum[41], A. Lasenby[6,38], N. Lavonen[1], C. R. Lawrence[36], C. Leto[2], E. Lindfors[45], N. Mandolesi[26], M. Massardi[22], W. Max-Moerbeck[42], P. F. Michelson[47], M. Mingaliev[44], P. Natoli[16,2,26], I. Nestoras[41], E. Nieppola[1,17], K. Nilsson[17], B. Partridge[18], V. Pavlidou[42], T. J. Pearson[8,29], P. Procopio[26], J. P. Rachen[40], A. Readhead[42], R. Reeves[42], A. Reimer[31,47], R. Reinthal[45], S. Ricciardi[26], J. Richards[42], D. Riquelme[30], J. Saarinen[45], A. Sajina[11], M. Sandri[26], P. Savolainen[1], A. Sievers[30], A. Sillanpää[45], Y. Sotnikova[44], M. Stevenson[42], G. Tagliaferri[21], L. Takalo[45], J. Tammi[1], D. Tavagnacco[24], L. Terenzi[26], L. Toffolatti[9], M. Tornikoski[1], C. Trigilio[20], M. Turunen[1], G. Umana[20], H. Ungerechts[30], F. Villa[26], J. Wu[39], A. Zacchei[24], J. A. Zensus[41], and X. Zhou[39]

Blazars are highly variable sources, in order to compare data with model predictions it is important to have simultaneous data. Moreover, blazars emit non-thermal radiation from radio to γ-ray, therefore multi-frequency observations are needed.

Having Planck, Swift, and Fermi simultaneously in orbit is a huge opportunity for studying blazar properties. This has been possible thanks to a dedicated MoU between the three teams to share data, expertise, and observation time (Swift).

In fact, while Planck is doing its own scan of the sky and Fermi observes the entire sky every day, Swift has to point at a given source when is within the Planck field of view. We have now collected ~200 Swift ToO observations of ~5 ks each, for a total of ~1 Ms of observation time.

These data are complemented by ground-based radio and optical follow-up programs: APEX, ATCA, Effelsberg, IRAM, Medicina, Metsahovi, OVRO, RATAN, UMRAO, VLA, KVA, and Xinglong.

Sample selection

In order to minimize selection bias in the interpretation of the results, we have adopted different criteria to select the list of sources to be observed:

- γ-ray flux limited sample: Fermi-LAT 3-month Bright Source List, |b| >10°, TS>100, S5GHz>1Jy, for a total of 50 sources
- hard X-ray flux limited sample: Swift-BAT 54-month source catalog, S15-150KeV > 10-11 erg cm-2 s-1, S5GHz>100 mJy, for a total of 34 sources
- soft X-ray flux limited sample: Rosat/RASS Bright Source Catalog (1RXS), count rate > 0.3 cts/s in the 0.1-2 KeV energy band, S5GHz>200mJy, for a total of 43 sources

The total is 105 sources (some are present in more than one sample), to be compared with the 104 sources in the radio flux limited sample used in the companion paper The Planck collaboration, A&A, 536:A14, 2011.

Spectral Energy Distributions

We have used the ASDC SED builder tool (publicly available from ASDC website http://tools.asdc.asi.it/SED/) to build the SED for all the sources in our sample.

In all the SEDs

- simultaneous data are shown in red
- quasi-simultaneous data (e.g., Fermi 2m, ERCSC, non-simultaneous dedicated ground-based follow up) are shown in green
- Fermi 27m data are shown in blue
- Archival data are shown in light gray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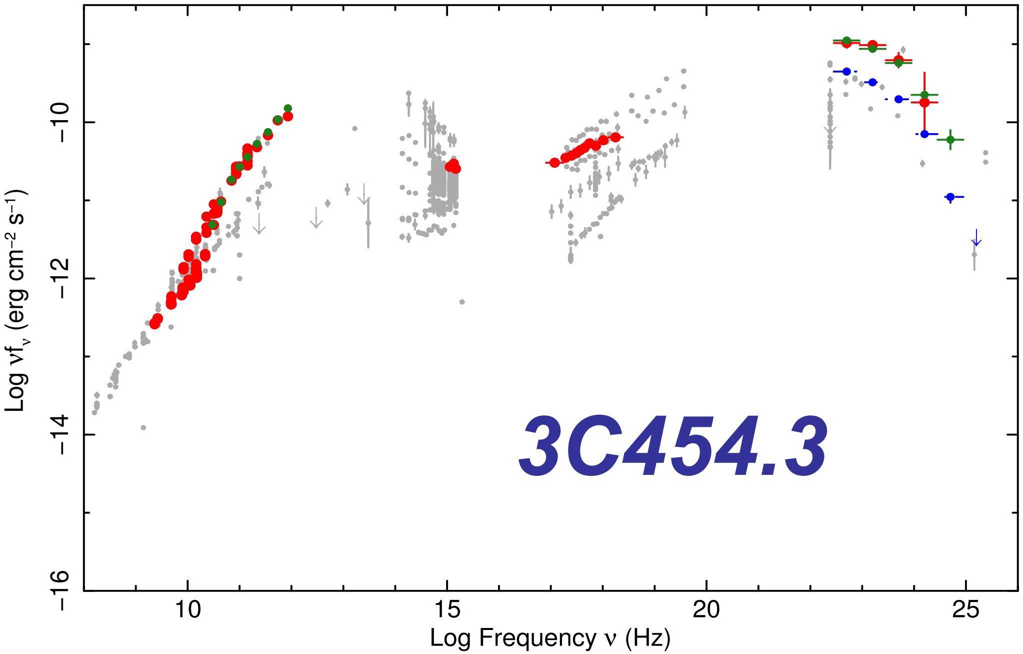
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Log Frequency ν (Hz)
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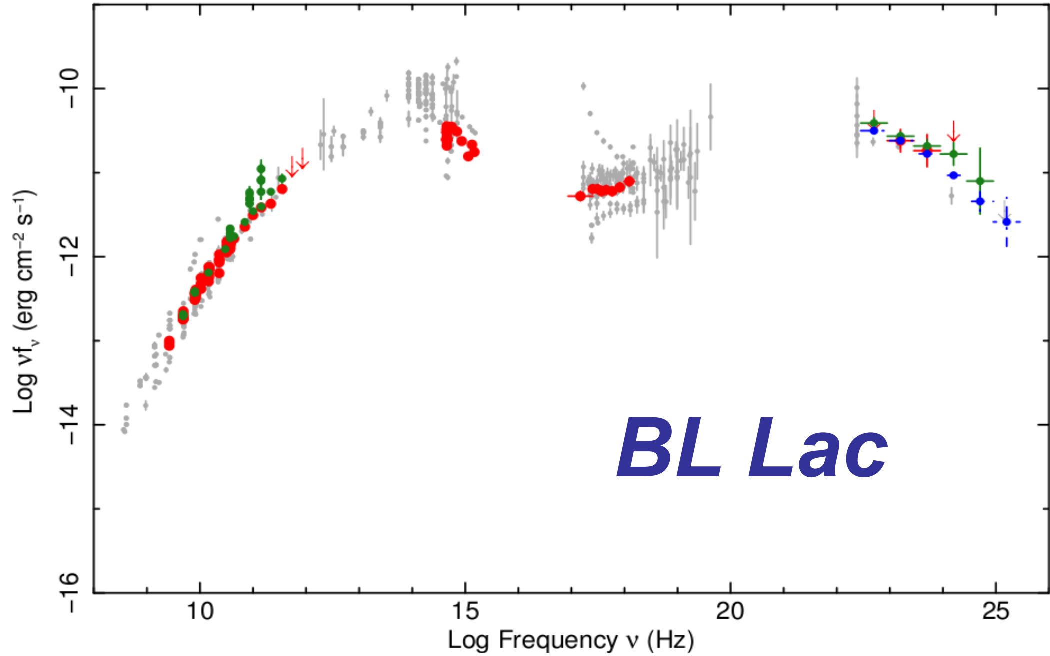
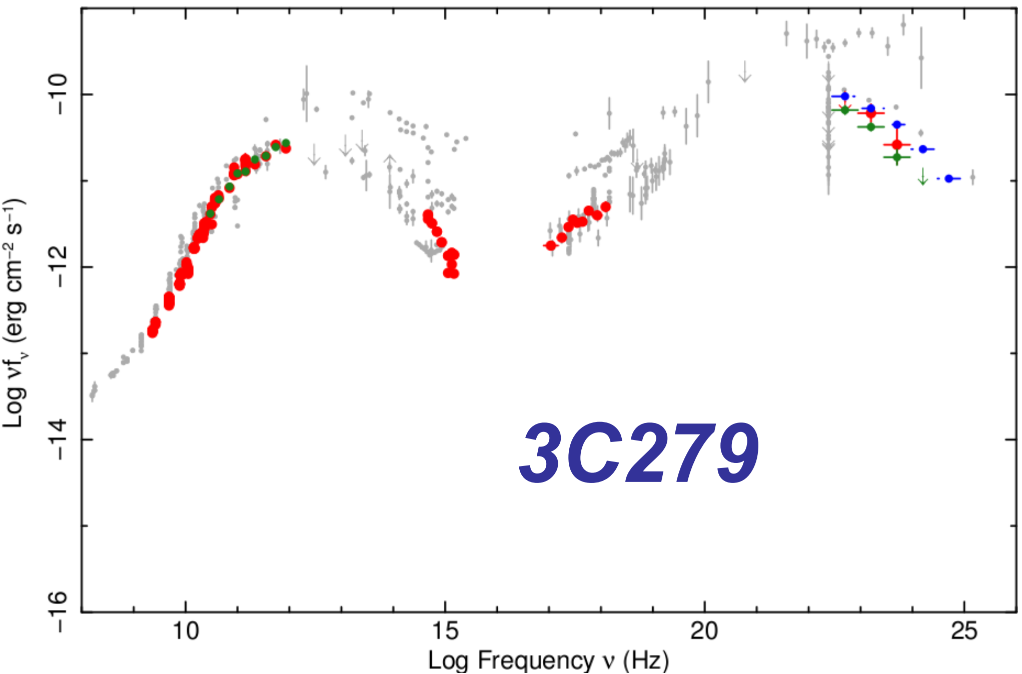
−12
−14
−16
10
15
20
25


BL Lac
Log νf_ν (erg cm^-2 s^-1)
Log Frequency ν (Hz)
−10
−12
−14
−16
10
15
20
25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Log νf_ν (erg cm^-2 s^-1)
Log Frequency ν (Hz)
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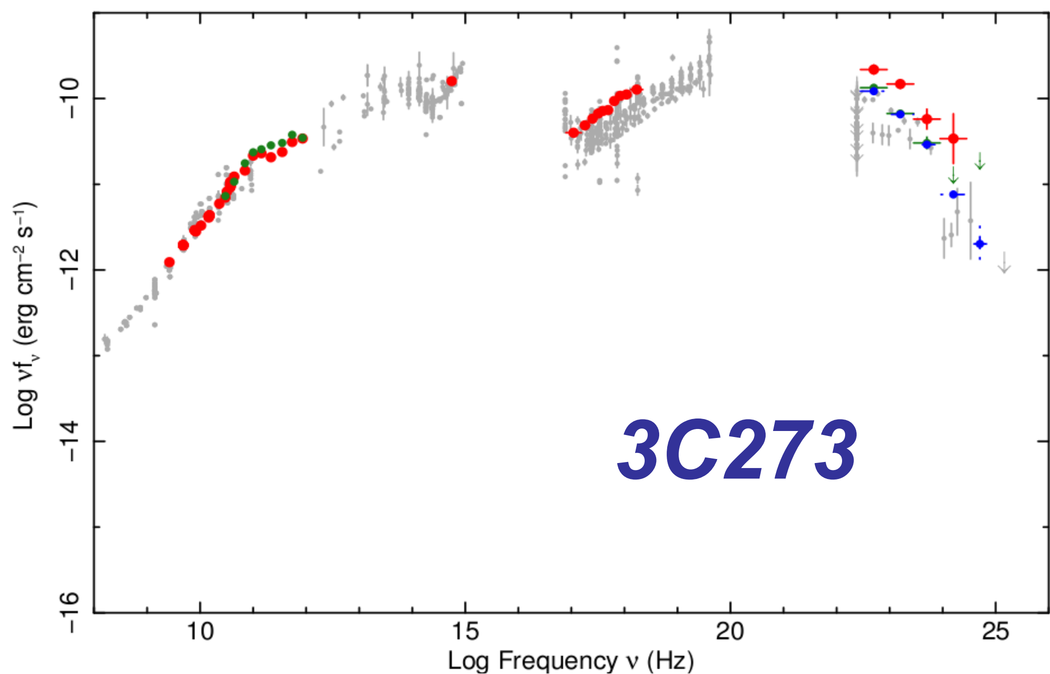
−16
10
15
20
25


3C273
Log νf_ν (erg cm^-2 s^-1)
Log Frequency ν (Hz)
−10
−12
−14
−16
10
15
20
25

Thermal signatures in the SEDs

In addition to the non-thermal emission coming from the jet, blazars show also thermal emission coming from the accretion into the central black hole and from the host galaxy.

In order to properly analyze our SEDs, we have to account for these emissions. This is done by using two templates, one for the host galaxy (Scarpa et al, 2000) and one for the accretion coming from Vanden Berk et al, 2001, built from the average of over 2200 optical spectra of radio quiet QSOs from the SDSS (Optical Blue Bump).

The position of the OBB is adjusted by fitting the parameter $\alpha_{R\text{-}O(TH)}$ to the SEDs (only for FSRQ, for BL Lac we set upper limits).

The X-ray thermal emission (and confidence intervals) is estimated from the BB using the relationship given by Grupe et al, 2010:

$$\alpha_{UV-X(Radio-quietQSO)} = 0.114 * Log(L_{2500\AA}) - 1.177$$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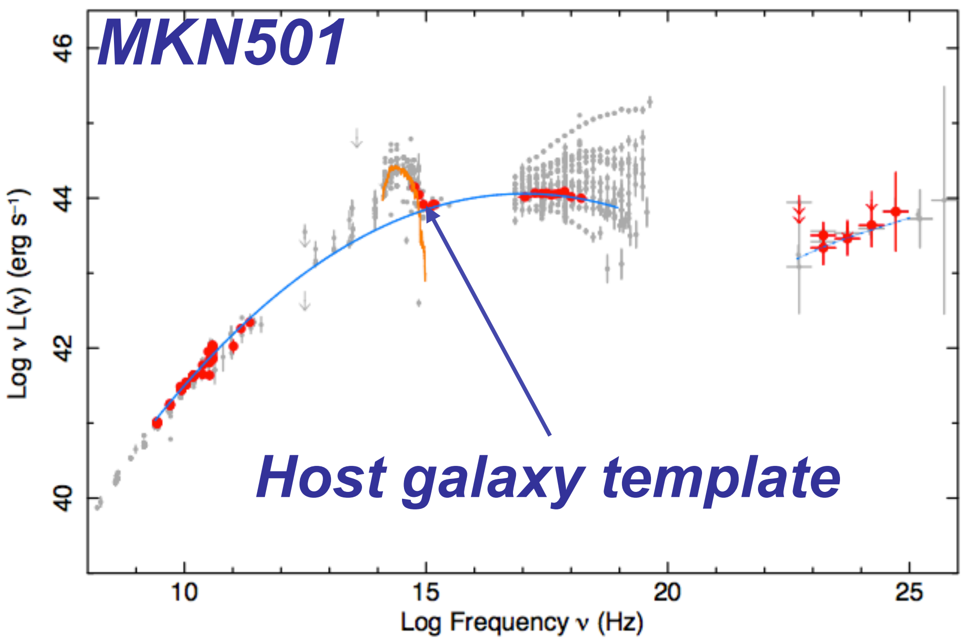
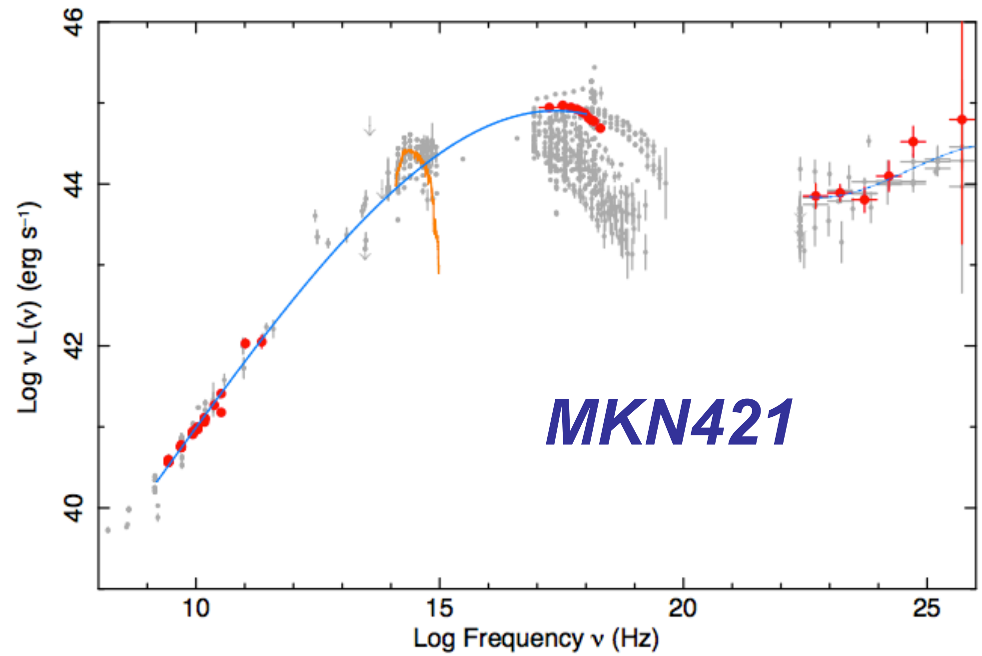
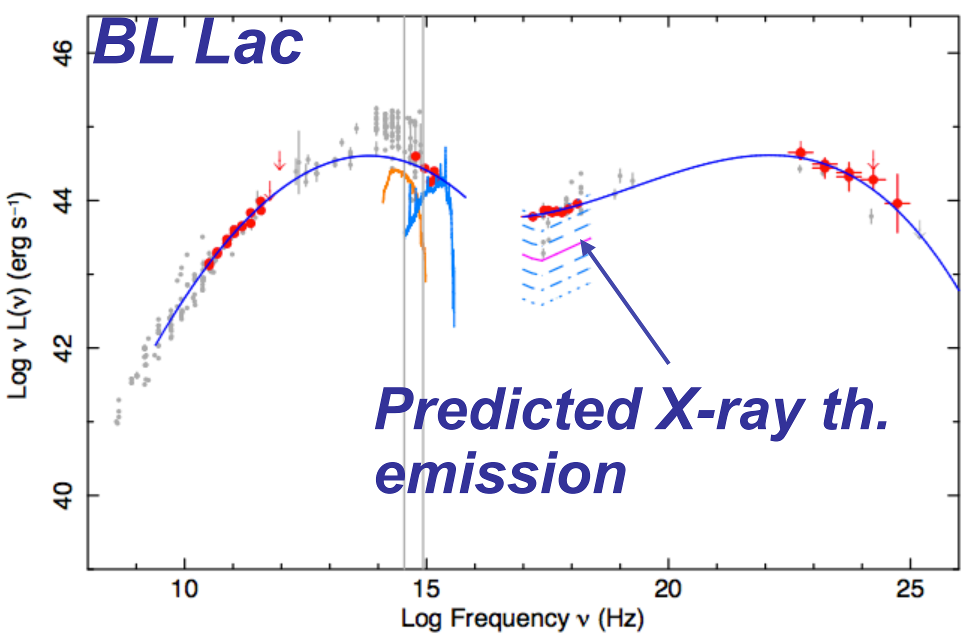
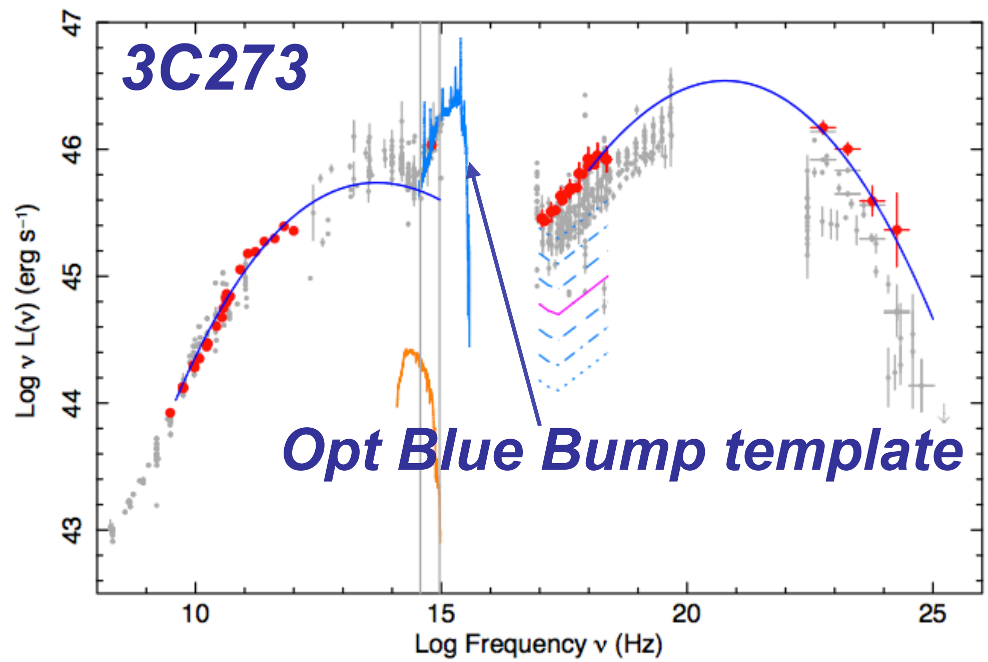

MKN501
Host galaxy template
Log ν L(ν) (erg s⁻¹)
Log Frequency ν (Hz)
40
42
44
46
10
15
20
25

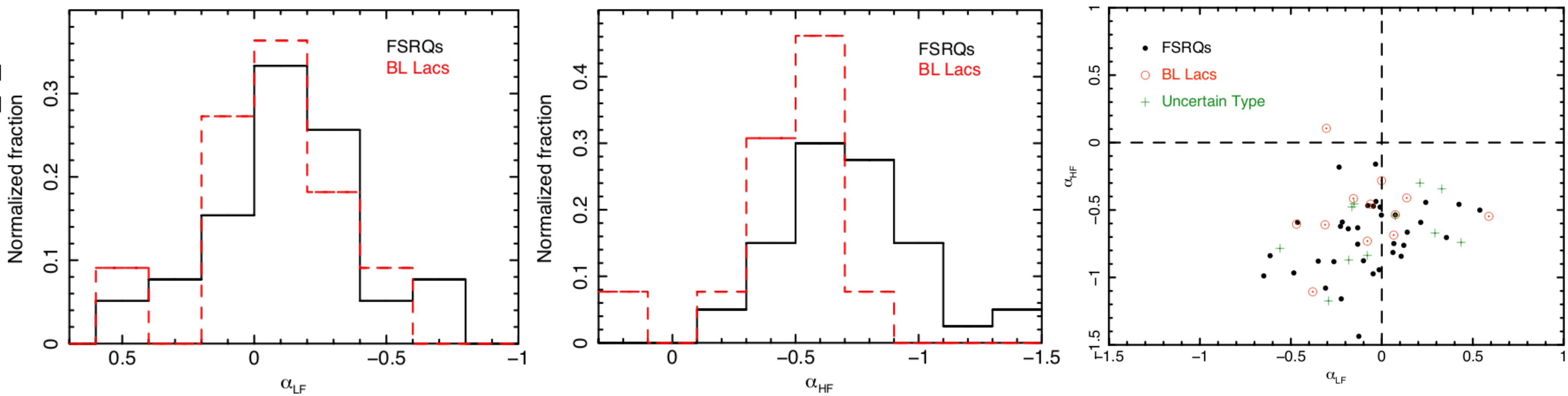

MKN421
Log ν L(ν) (erg s⁻¹)
Log Frequency ν (Hz)
40
42
44
46
10
15
20
25


BL Lac
Predicted X-ray th. emission
Log ν L(ν) (erg s⁻¹)
Log Frequency ν (Hz)
40
42
44
46
10
15
20
25


3C273
Opt Blue Bump template
Log ν L(ν) (erg s⁻¹)
Log Frequency ν (Hz)
43
44
45
46
47
10
15
20
25

Radio spectral slope

Using Planck data together with the ground-based follow-up, we probes the spectral shape from ~1GHz to ~1THz.



Our results confirm α_{LF}~0 and α_{HF}~-0.65, with a break at ν~70GHz, in good agreement with those obtained for the ERCSC.

FSRQs are slightly steeper than BL Lacs: α_{HF}~-0.7 vs α_{HF}~-0.5, this seems to be correlated with the position of the synchrotron peak, which is higher for BL Lacs than for FSRQs.

Correlation between fluxes in different bands

Several papers report a positive correlation between radio and γ-ray fluxes, though with a large scatter which is usually explained with the lack of simultaneity in the data.

Moreover, samples used for this analysis are generally biased as they do not include upper limits for unseen sources in one of the two bands, but they only include sources that are bright in both frequency bands.

Here we use for the first time simultaneous data also taking into account upper limits, in order to test for correlation using all the sources in our samples.

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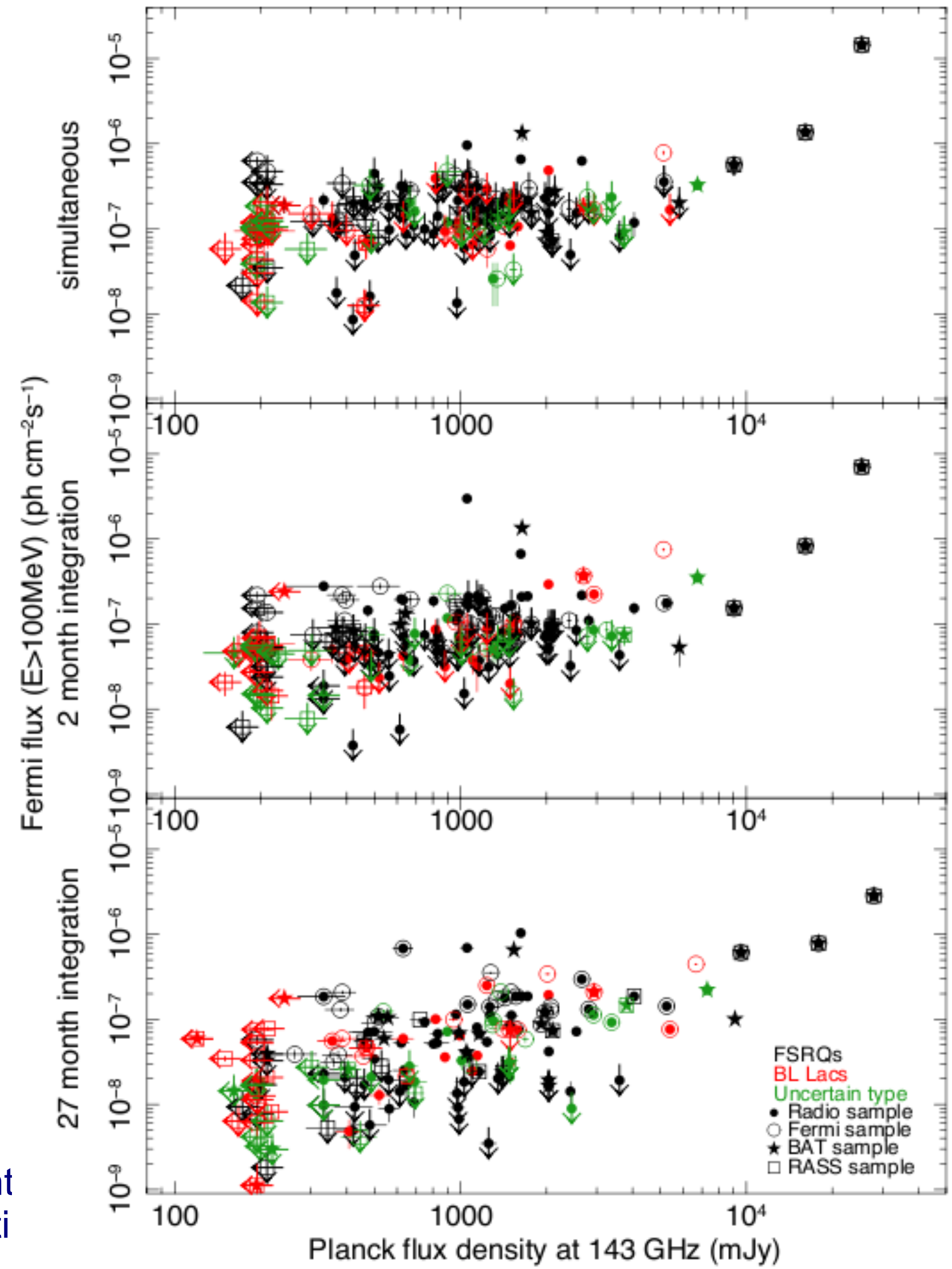
Microwave vs γ-ray

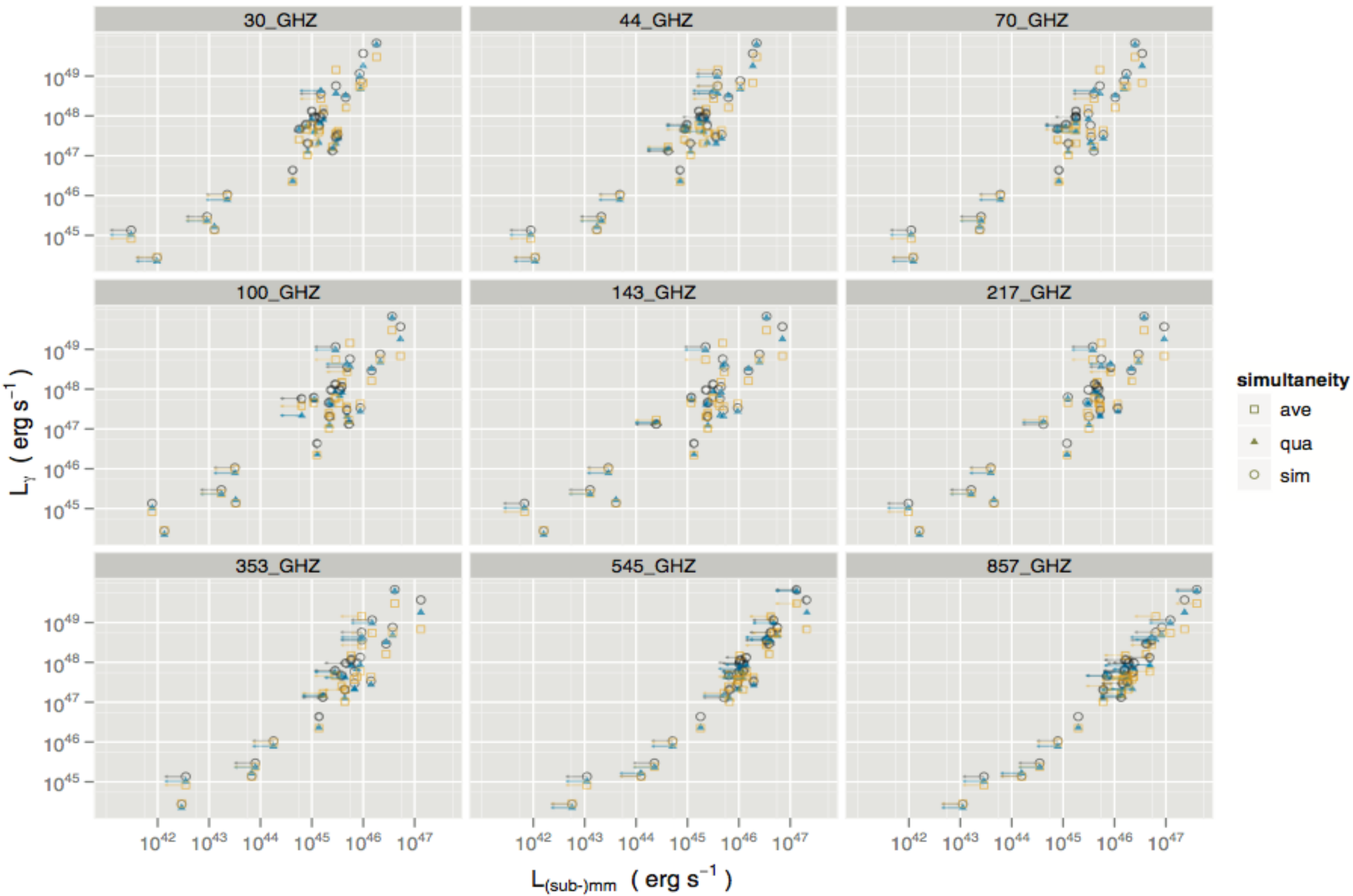
Despite the use of simultaneous data, there is a clear trend but no significant correlation (unless for the radio sample). However there are too many upper limits in the simultaneous data (especially BL Lacs in Swift-BAT and Rosat/RASS samples).

The correlation improves when increasing the integration period of the Fermi data. Note that the ERCSC period fully overlaps with the γ-ray 27m integration.

No major differences using radio flux densities at frequencies other than 143GHz.

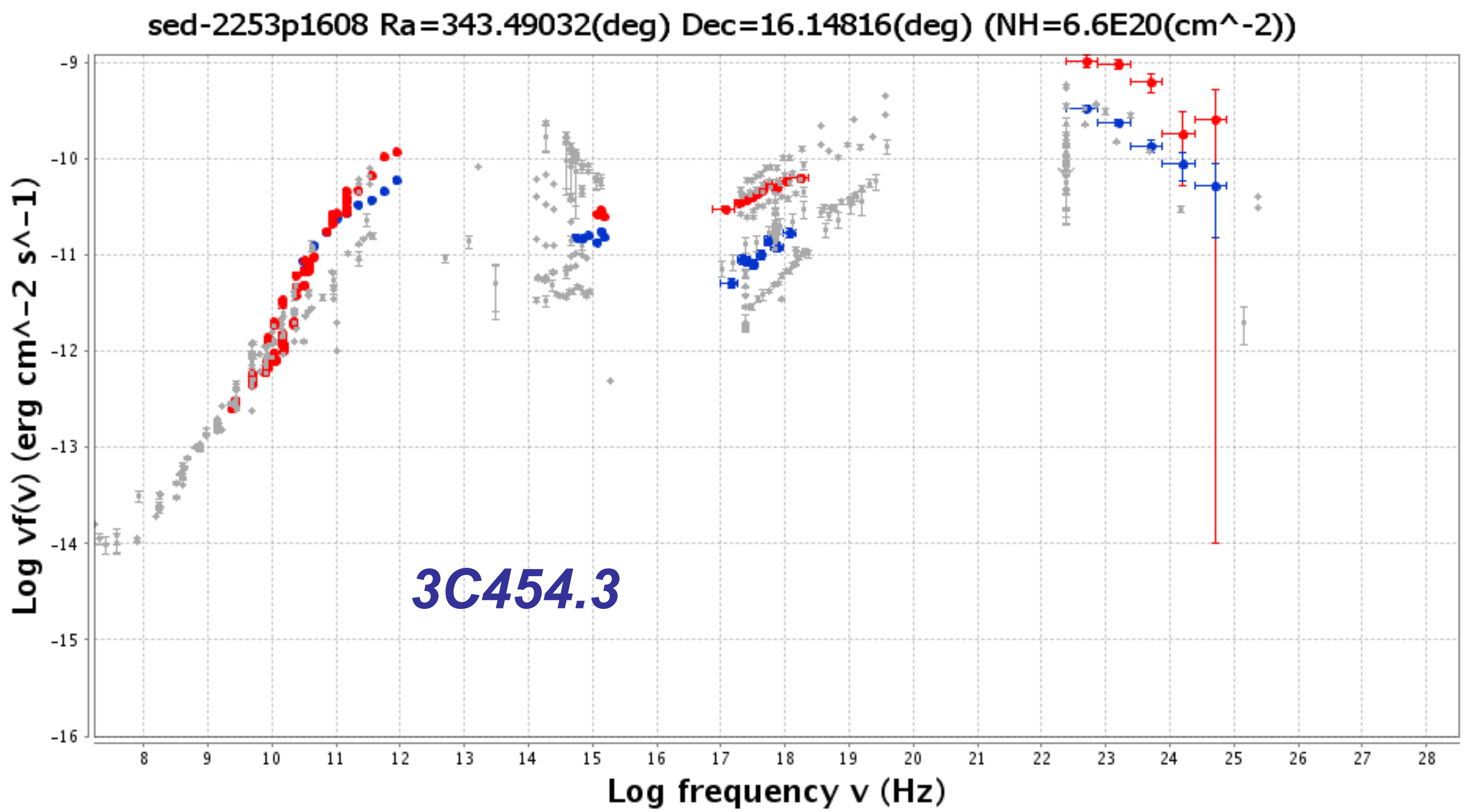


Stronger correlations are found on the same dataset when analysed using luminosity instead of flux (Leon-Tavares et al, ApJ, 754:23, 2012).



Suggestions for:

- the presence of multiple synchrotron components at radio frequencies while simultaneous γ-ray flux represents the emission of a single dominant component
- different dynamical time scales between radio and γ-ray



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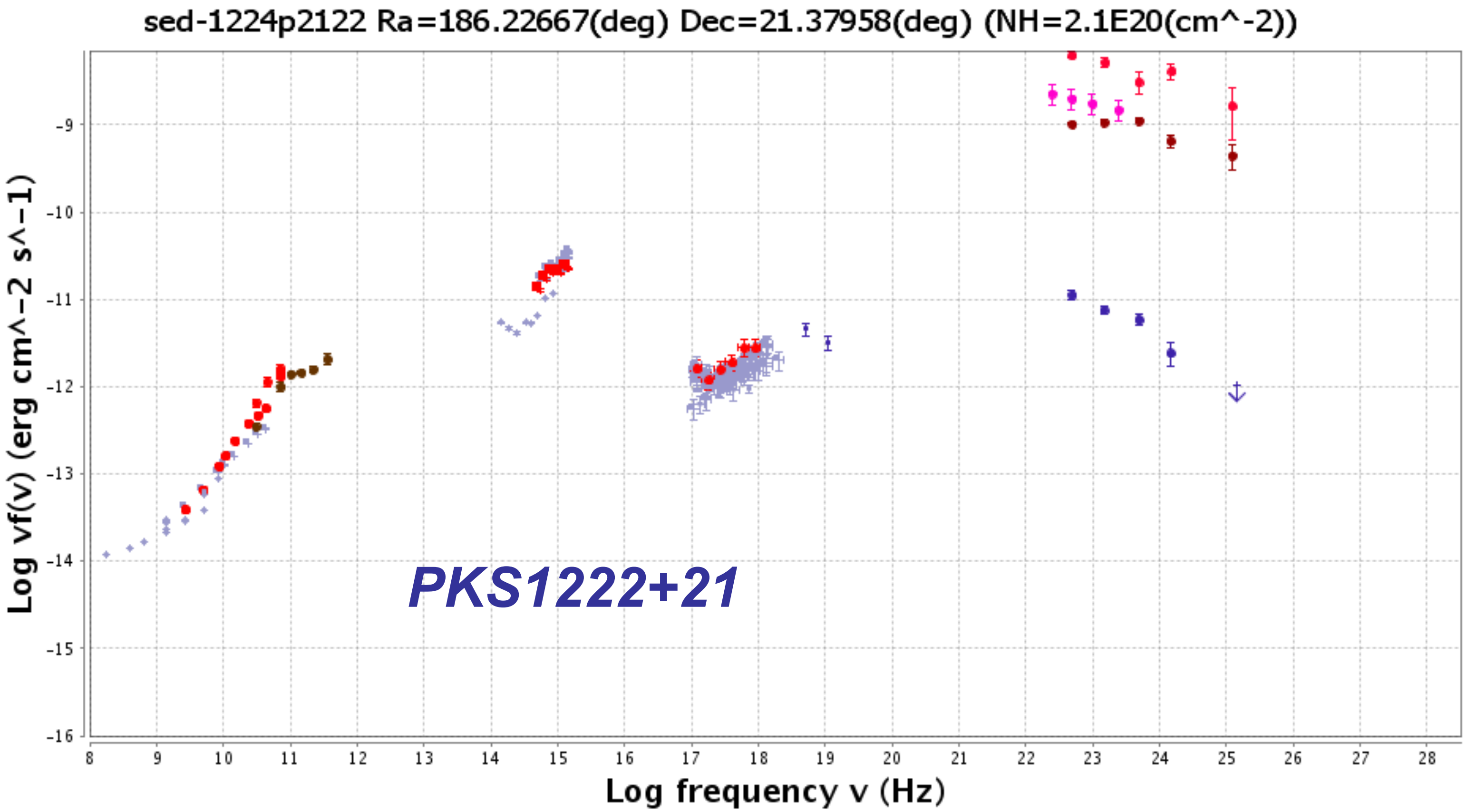

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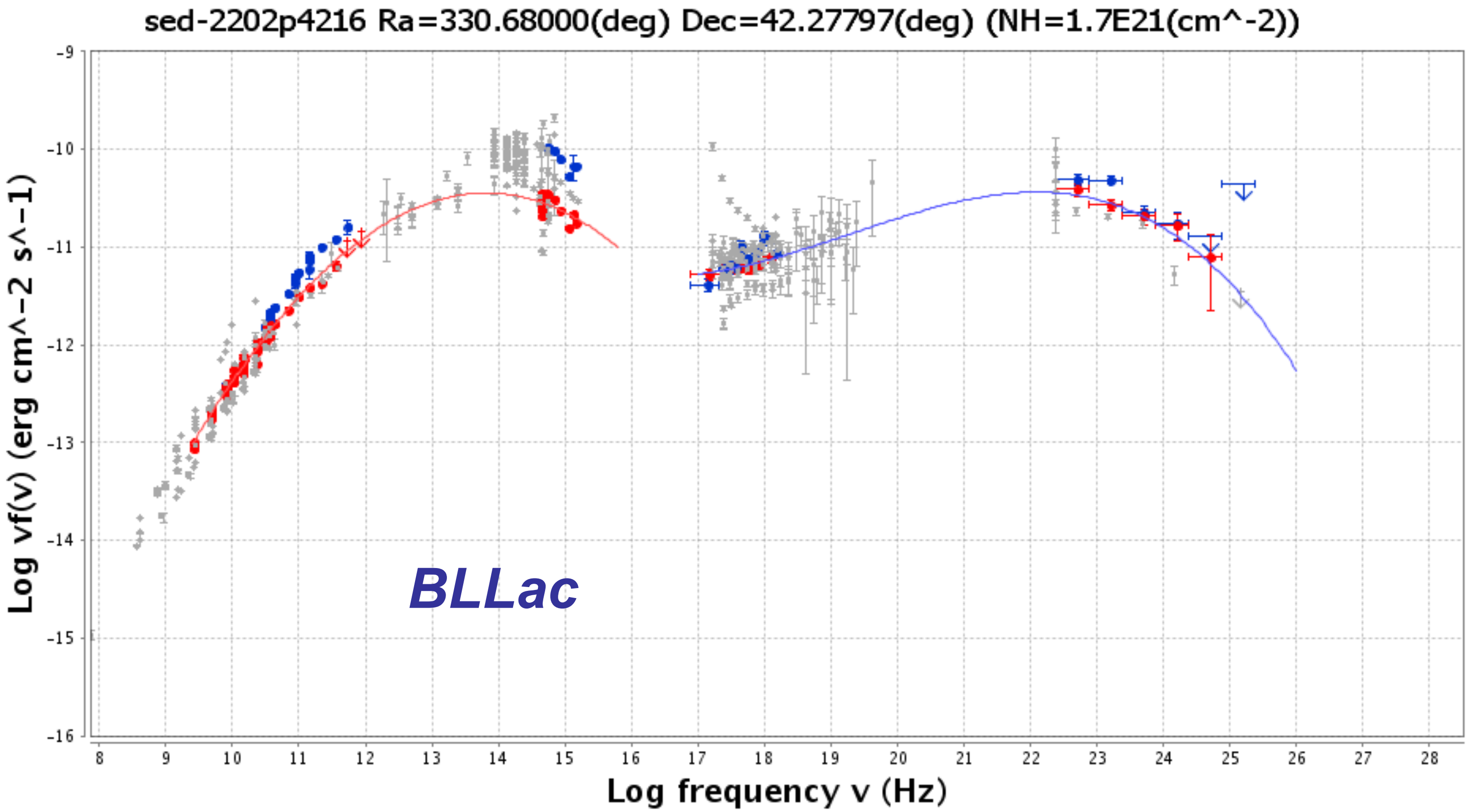
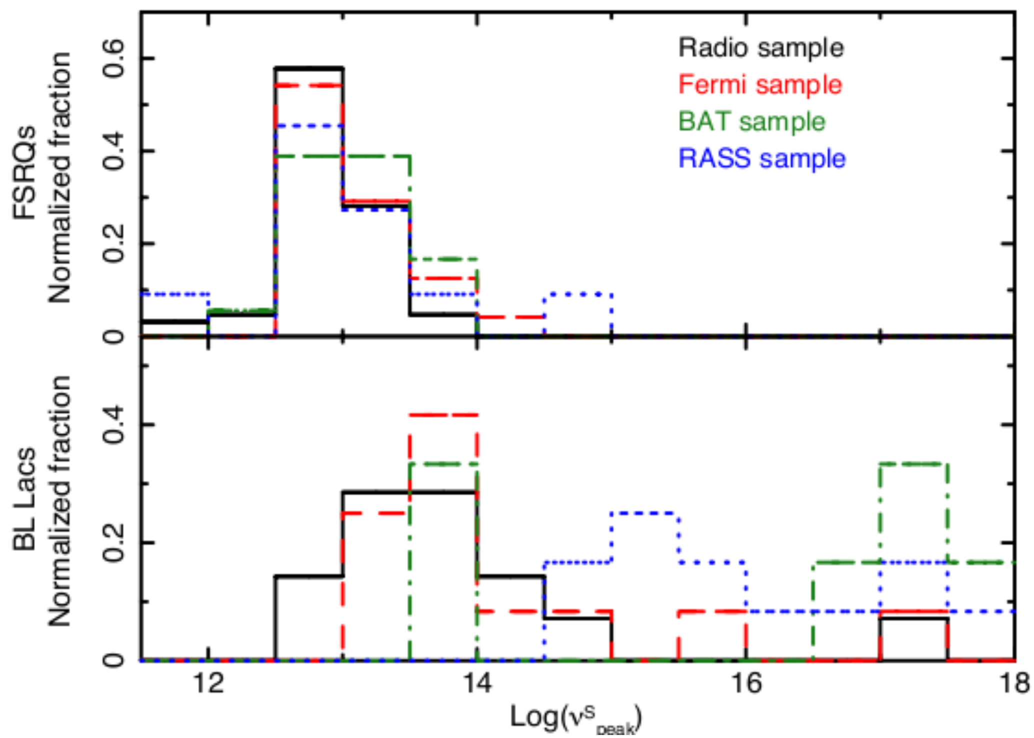


Synchrotron and IC peak distributions

We have estimated the position of both Synchrotron and IC peaks accounting for thermal emission as described in the previous slides.

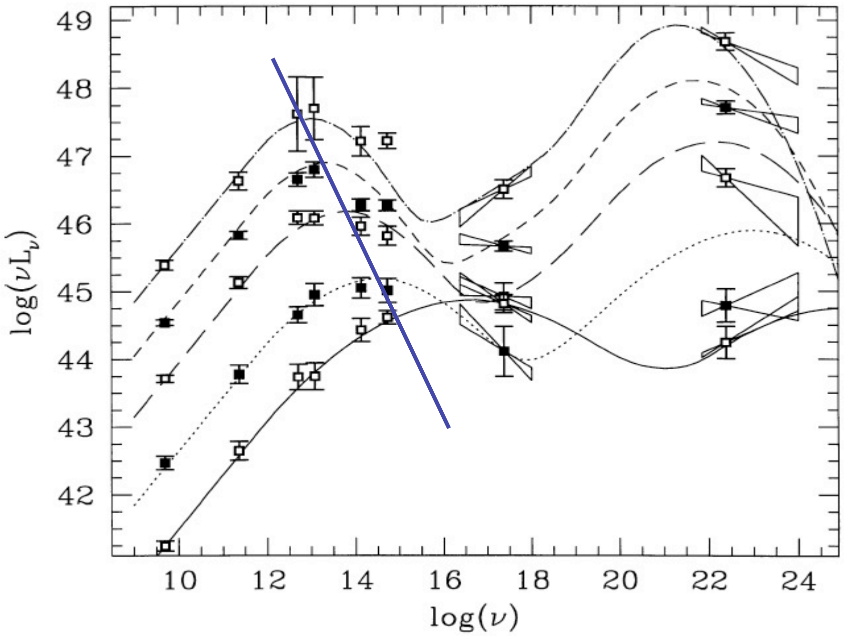
FSRQs show the same synchrotron peak distribution for all the samples with an average of <Log(ν_p)>~13.1, while BL Lacs are very spread depending on the selection method.

This is true also for the IC peak distribution although with more scatter, where we found an average of <Log(ν_p)>~22for FSRQs, and a wide spread for BL Lacs.



The Blazar Sequence

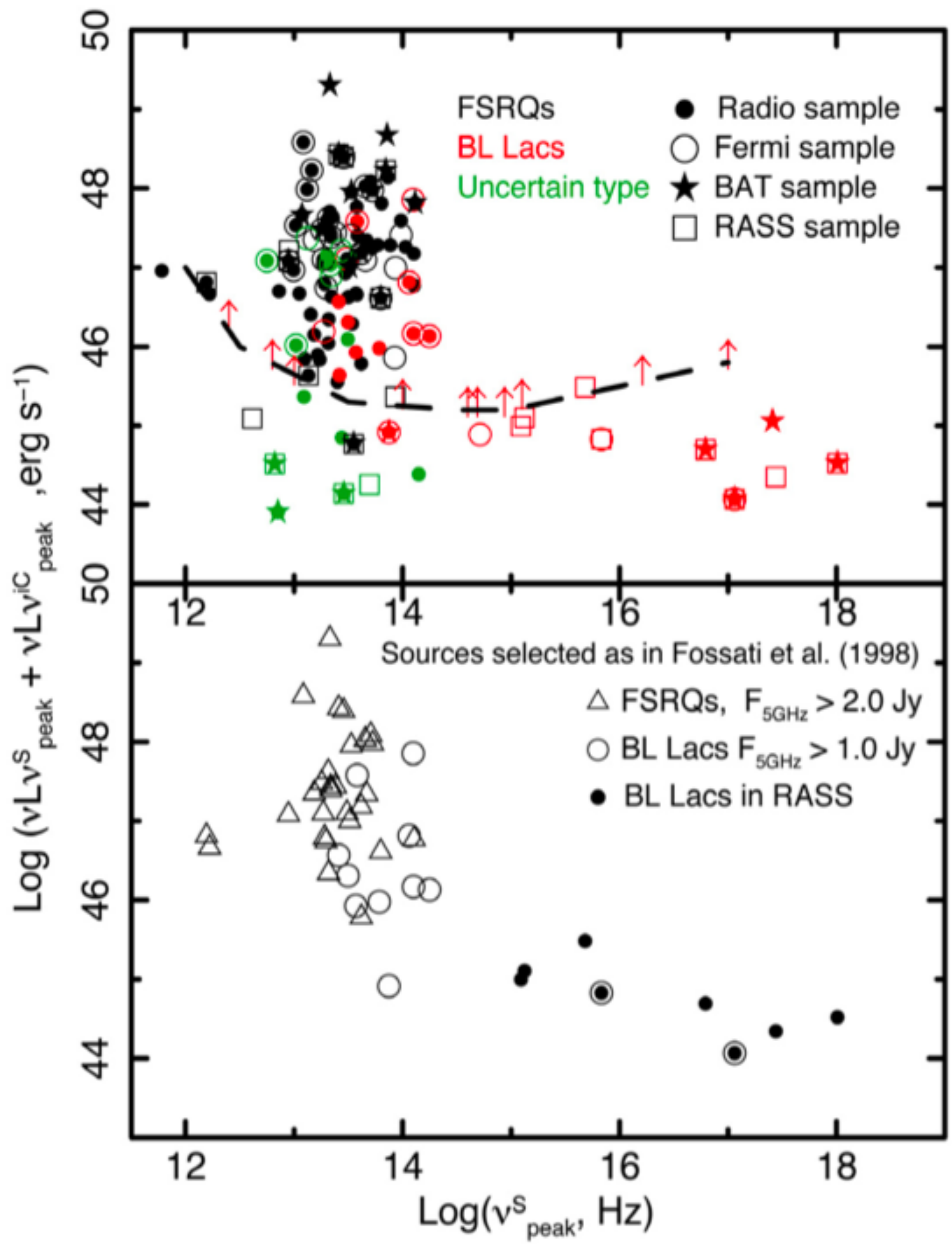
Fossati et al 1998: strong anti-correlation between the position of synchrotron peak and the peak power.



The dashed line represents the luminosity above which the optical non-thermal emission is 10 times larger than the host galaxy, and the area above this line cannot be populated by BL Lacs because it doesn't allow the estimation of the redshift.

A few BL Lacs are above the dashed line because their redshift has been estimated from emission lines in their optical spectra, with equivalent width is less then 5Å.

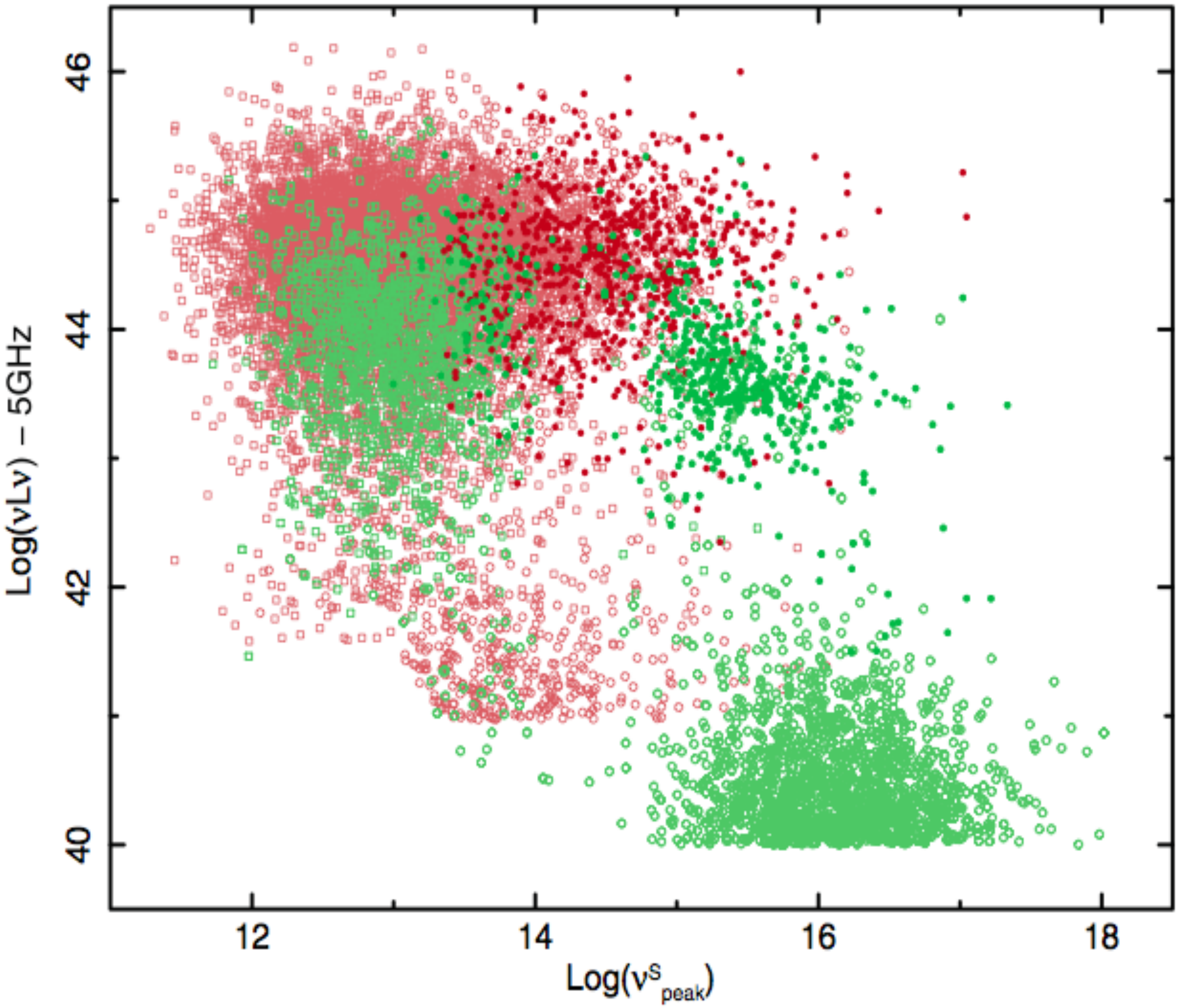
We do not see any anti-correlation supporting the Blazar Sequence. Moreover, by applying similar selection criteria as in Fossati et al we reproduce the blazar sequence, suggesting that this is a selection effect.



This interpretation of the blazar sequence is consistent with results obtained from MC simulations of X and radio selected samples of blazars in a simplified scenario (Giommi et al, MNRAS, 420:2899, 2012).

FSRQ = open squares
BLLac = open circles
Red = radio sample
Green = X-ray sample

Filled circles are BLLac objects with featureless optical spectra, that are likely to appear without measured redshift in a real survey.



MAC

What's next

We have just started exploiting Planck AGN data.

We have produced a blazar catalogue that will be published soon.

The first Planck catalogue, based on the 15 month nominal mission, will be released next March.

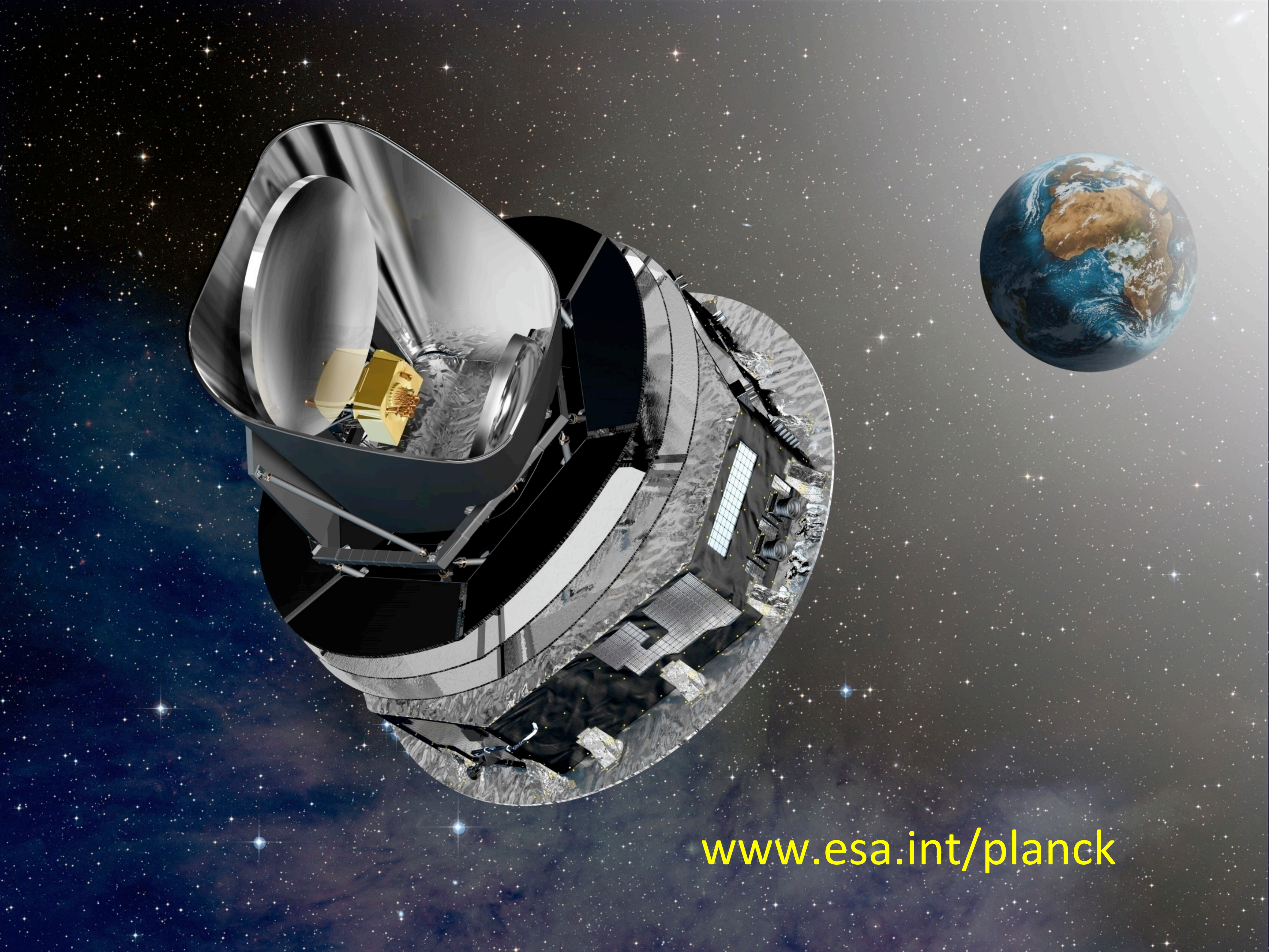
Planck HFI has collected 29 months of data and LFI has already reached 42 months of observations, therefore we expect significant improvements for the second data release in 2014.

Moreover, variability has not been considered so far.

Finally, Planck is sensitive to polarization, and this will provide additional interesting information.

The scientific results that have been presented are a product of the Planck Collaboration, including individuals from more than 100 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.


www.esa.int/planck