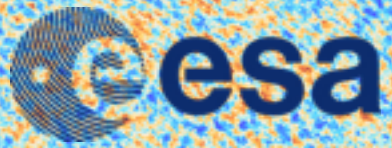


Planck 2015 results. XXV.
Diffuse low-frequency Galactic foregrounds

A&A (in publication), arXiv: 1506.06660

Corresponding authors: Clive Dickinson, Paddy Leahy
Significant contributions by Mike Peel, Matias Vidal

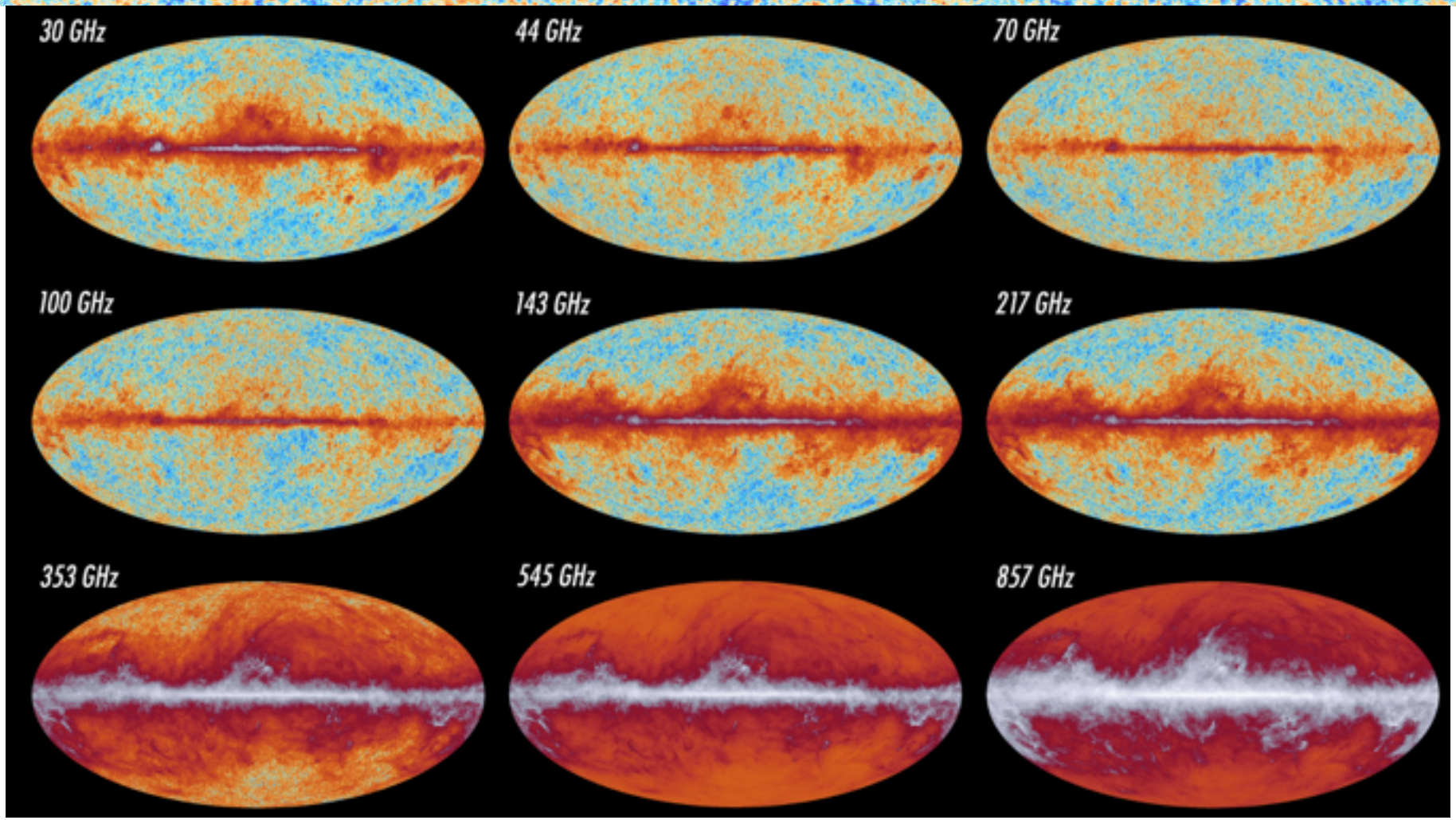
Mike Peel

Jodrell Bank Centre for Astrophysics,

The University of Manchester

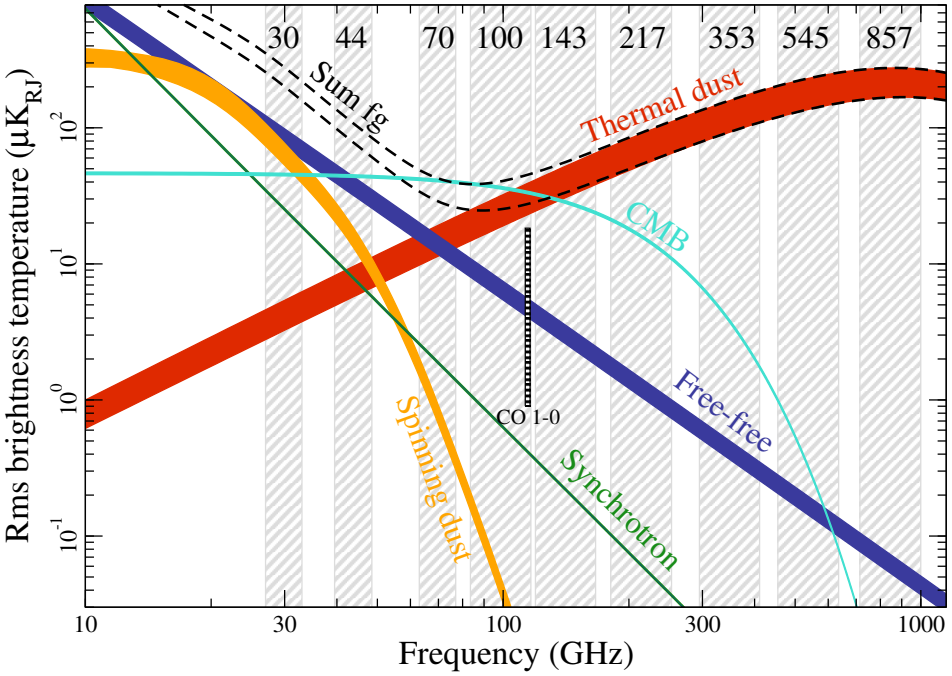
on behalf of the Planck Collaboration

Overview

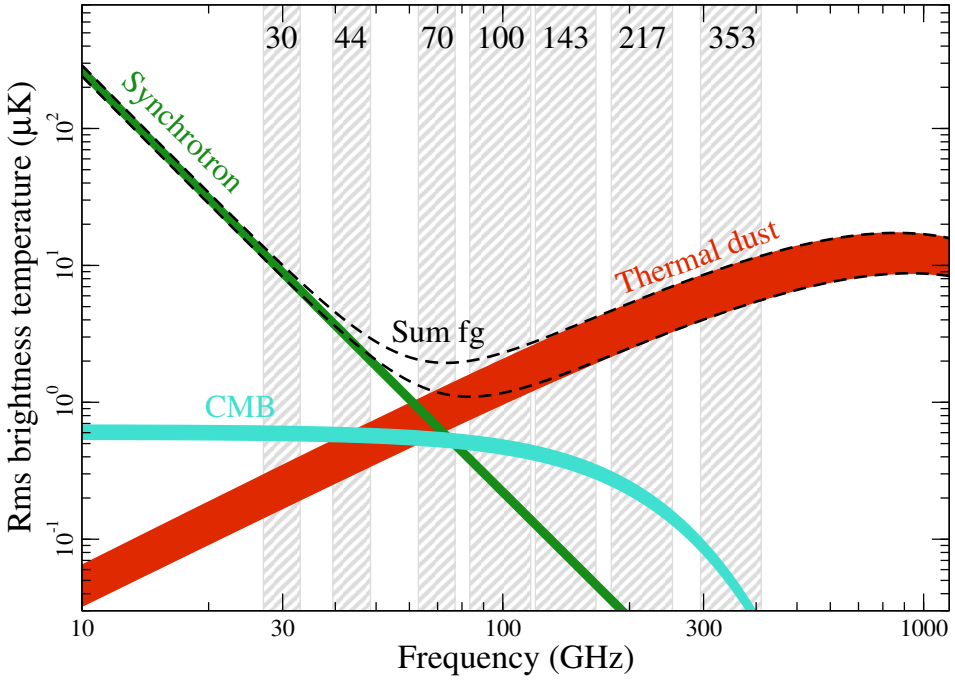

30 GHz
44 GHz
70 GHz
100 GHz
143 GHz
217 GHz
353 GHz
545 GHz
857 GHz

Overview

Total intensity



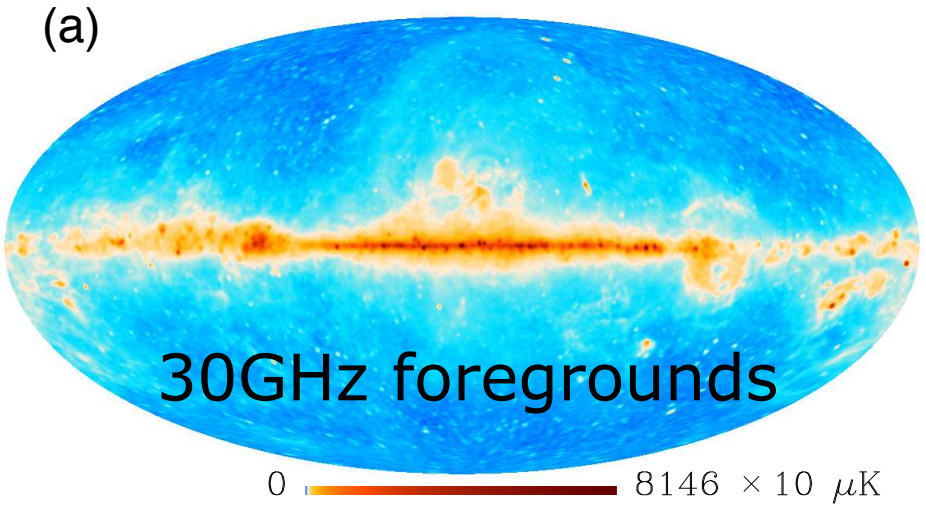
Polarization

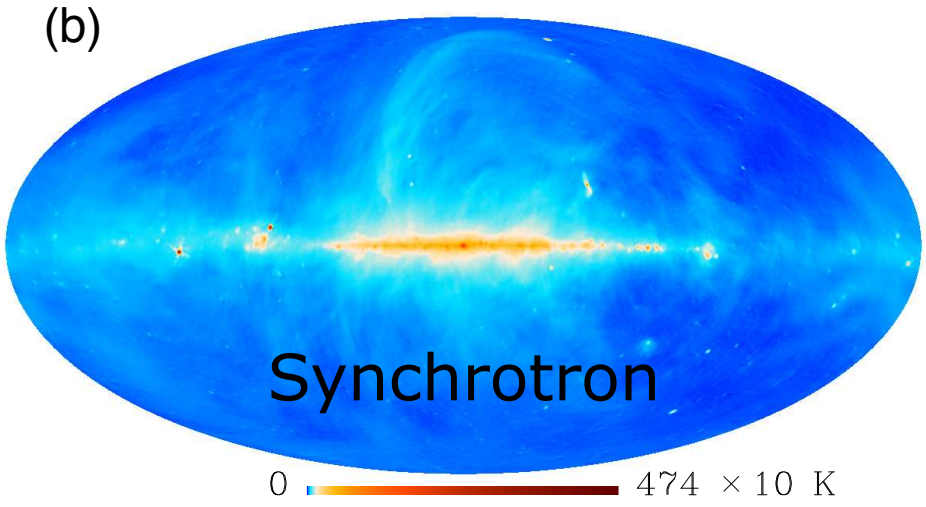


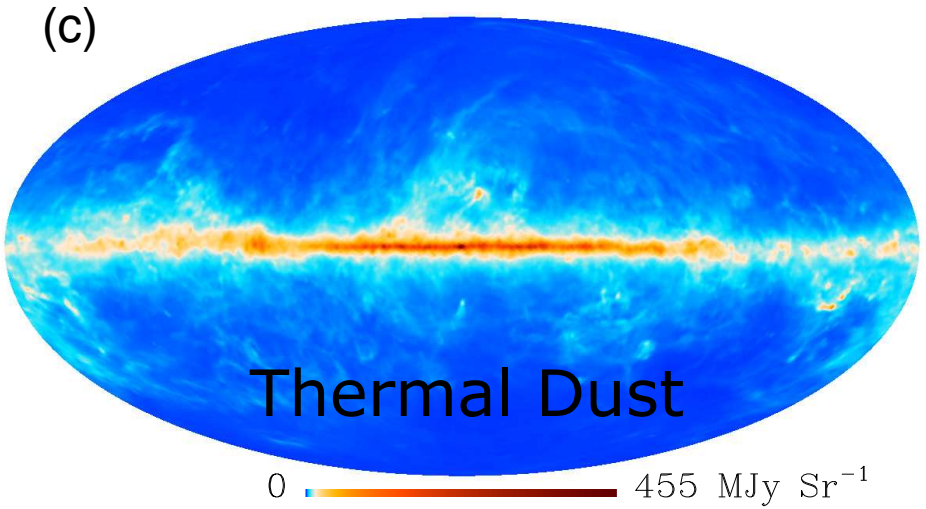
Dominated by Galactic emission at nearly every frequency.
Need to understand them well to subtract them.
Also interesting in their own right!

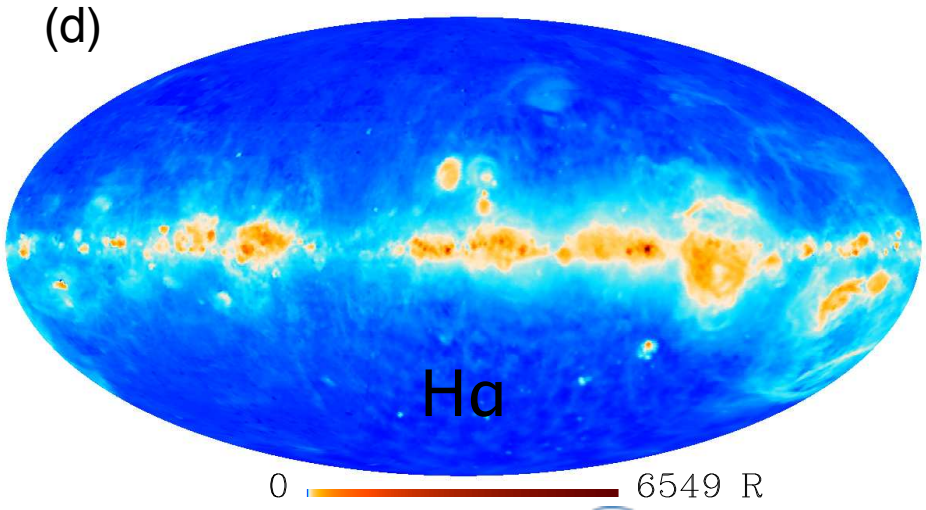
(Figures from Planck 2015 results. X.)

Overview



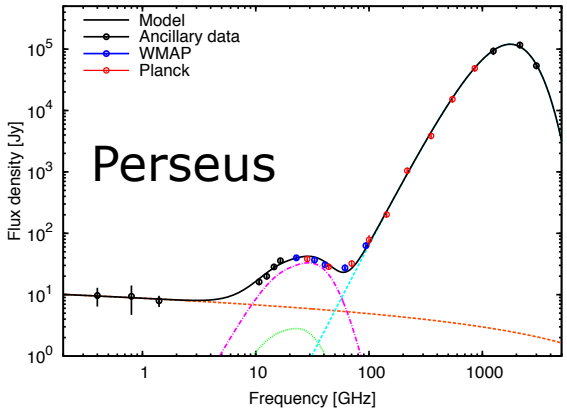


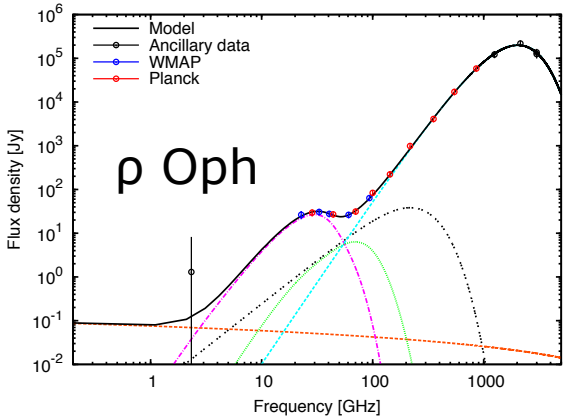


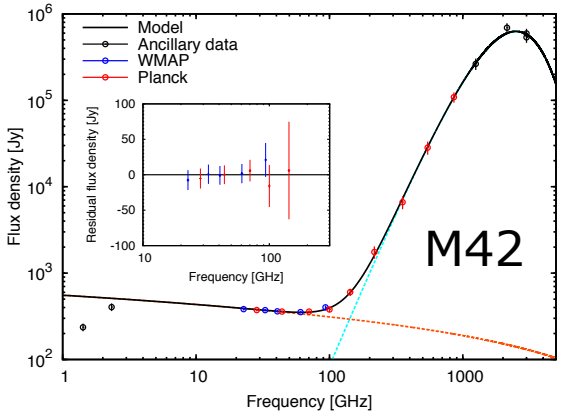


(Figures from Planck 2015 results. XXV.)

Planck early results

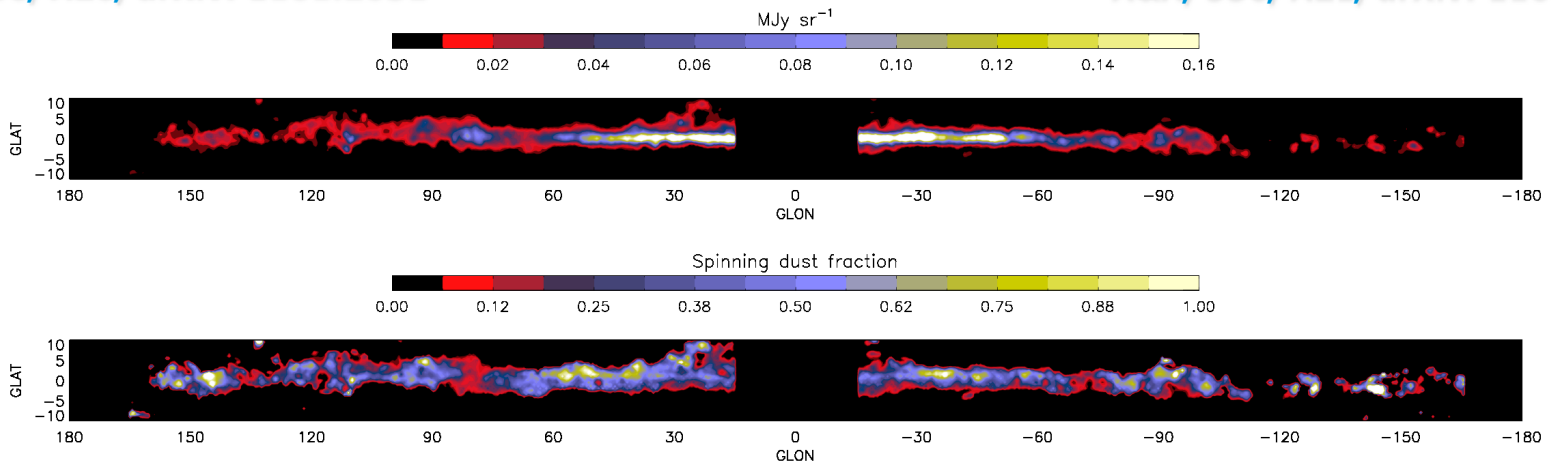






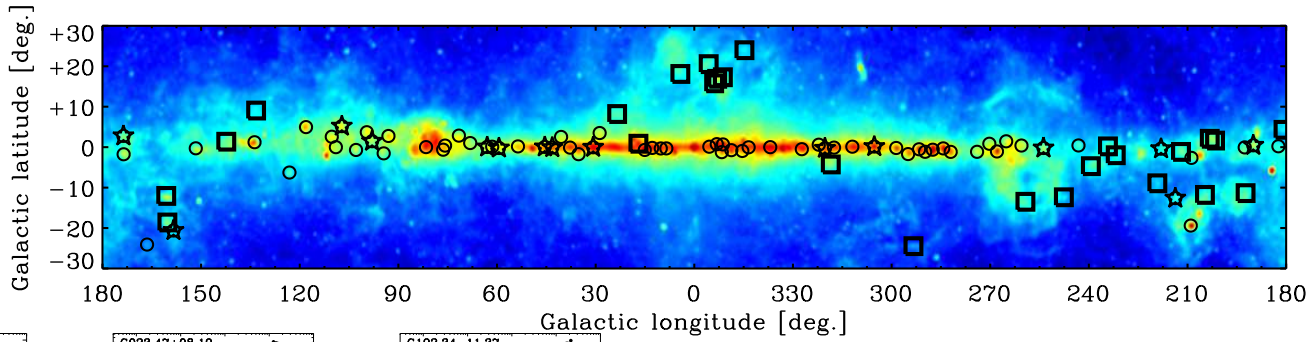
Planck early results. XX. New light on anomalous microwave emission from spinning dust grains
A&A, 536, A20, arXiv: 1101.2031

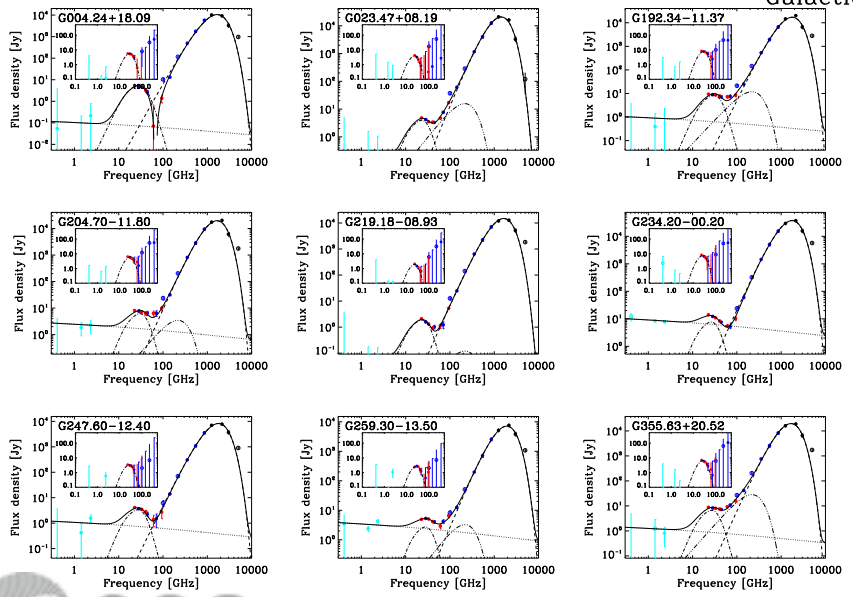
Planck early results. XXI. Properties of the interstellar medium in the Galactic plane
A&A, 536, A21, arXiv: 1101.2032

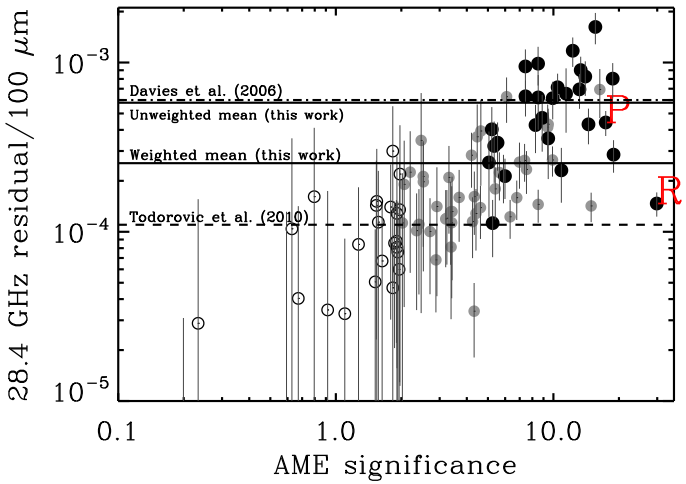


PIP XV: Planck AME study

Planck intermediate results. XV.
A study of anomalous microwave emission in Galactic clouds
A&A, 565, A103, arXiv: 1309.1357







PIP XV: Planck AME study

Planck intermediate results. XV.
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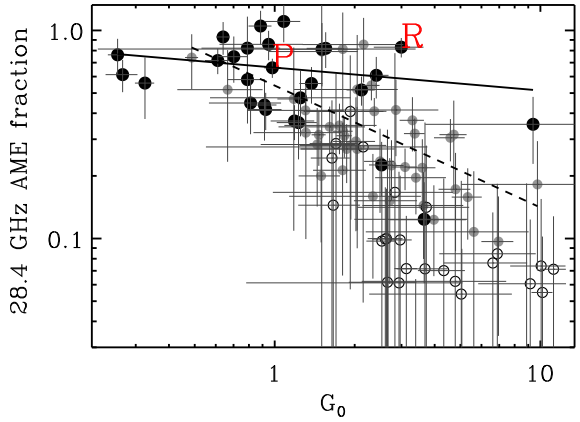
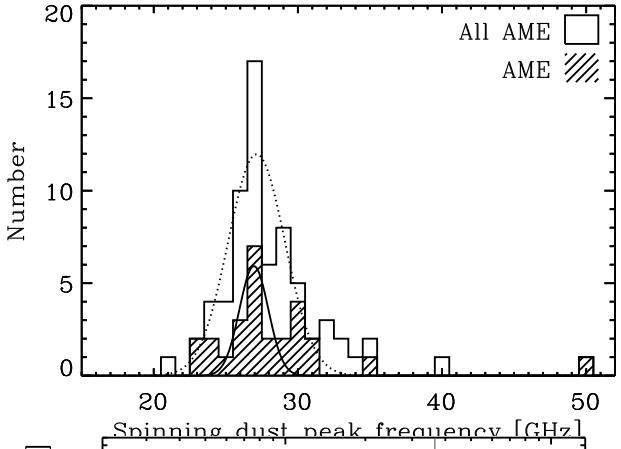
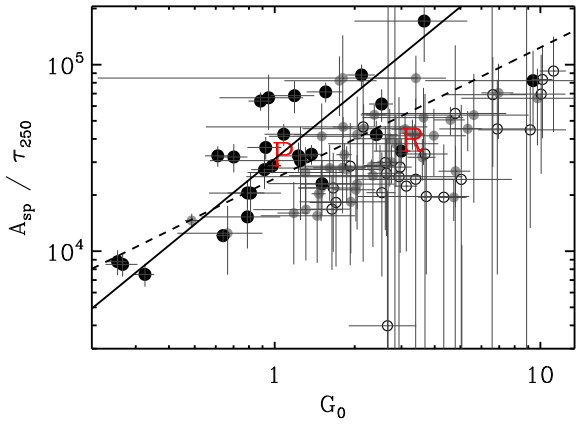
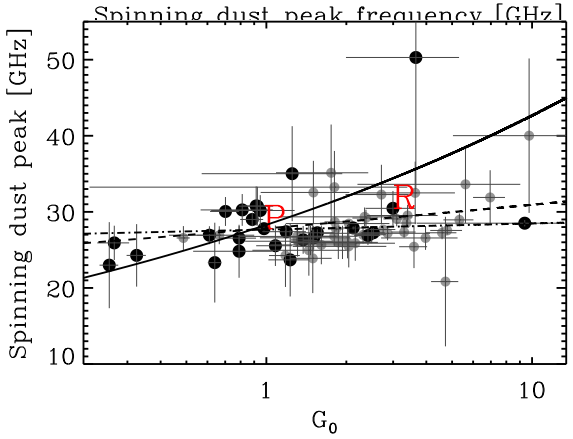
A&A, 565, A103, arXiv: 1309.1357



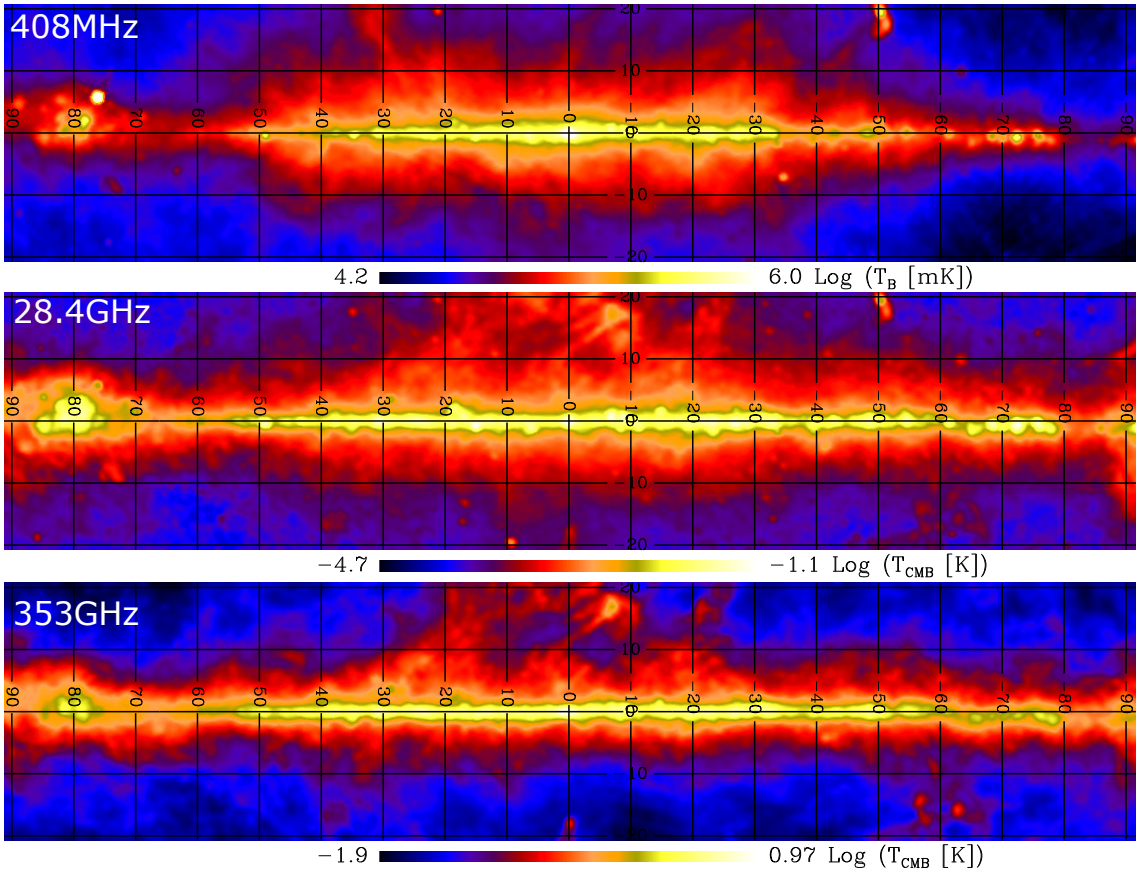


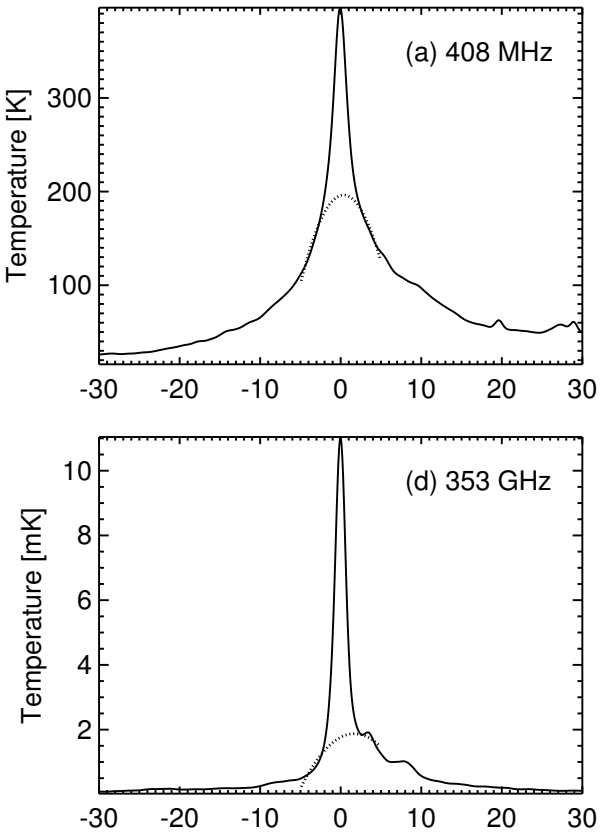




PIP XXIII: Galactic Plane

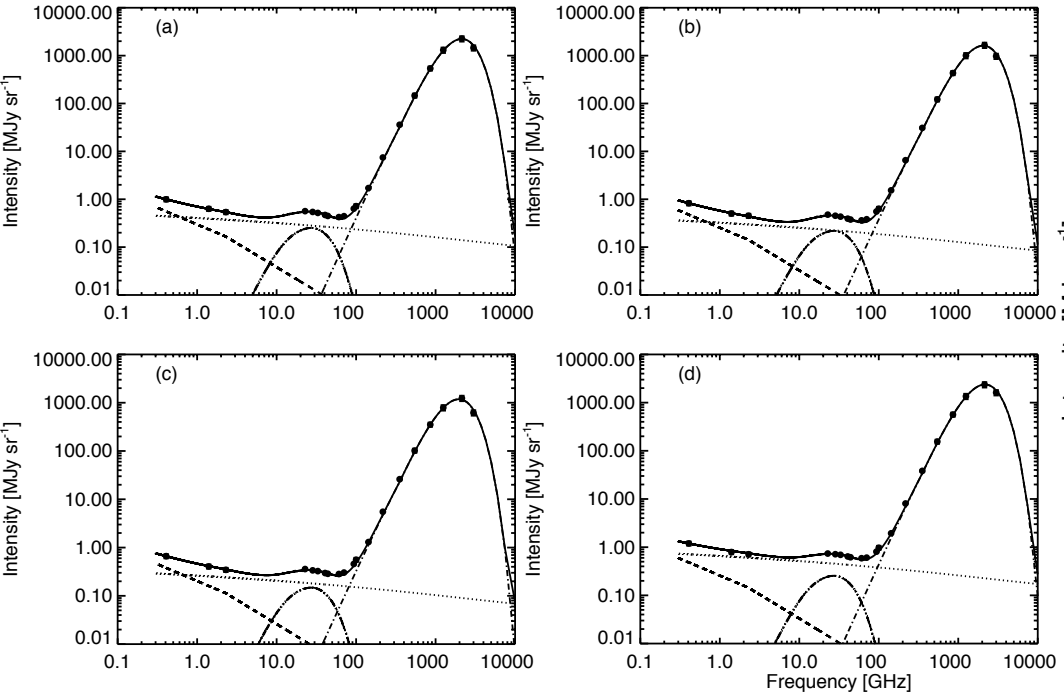
Planck intermediate results. XXIII.
Galactic plane emission components derived from Planck with ancillary data
A&A, 580, A13, arXiv: 1406.5093

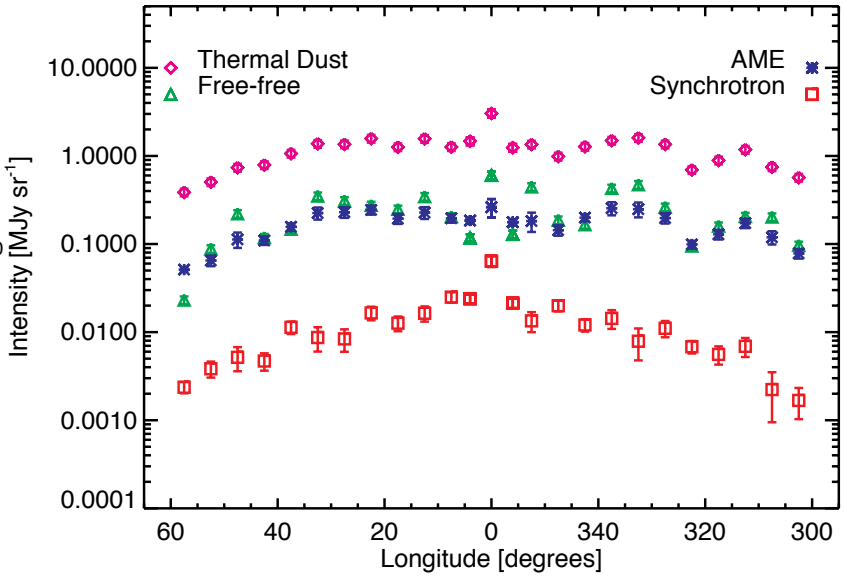




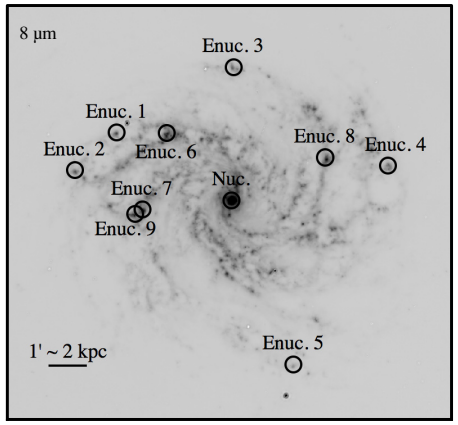
PIP XXIII: Galactic Plane

Planck intermediate results. XXIII.
Galactic plane emission components derived from Planck with ancillary data
A&A, 580, A13, arXiv: 1406.5093

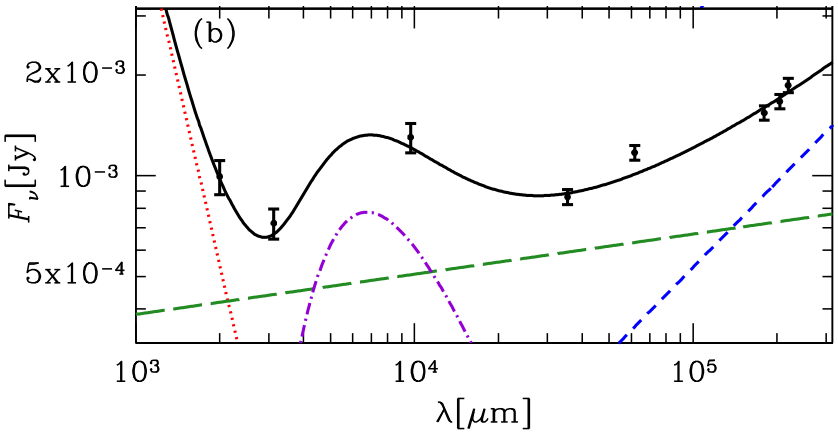




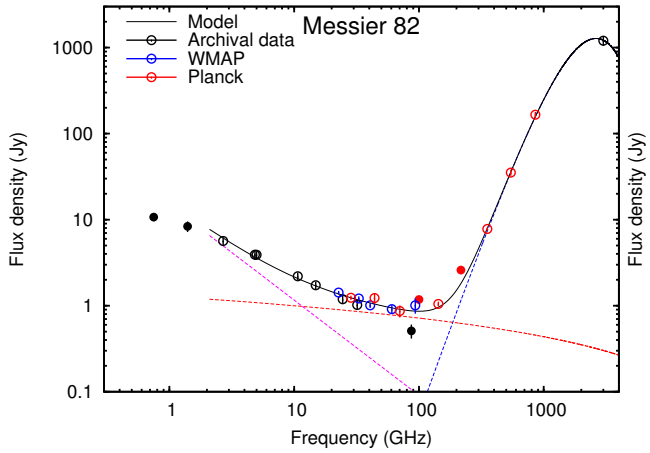
AME in nearby galaxies

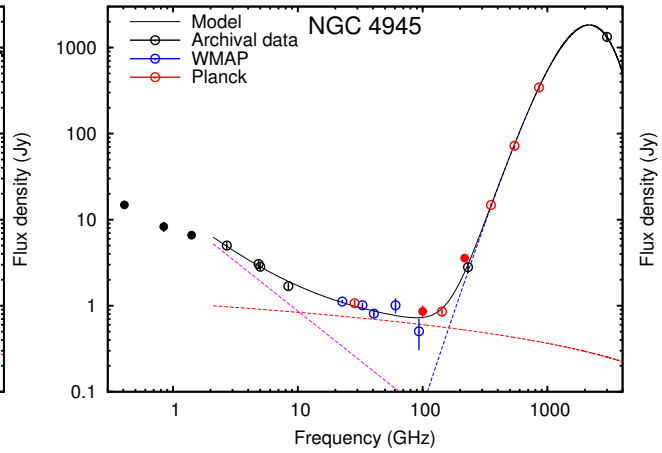


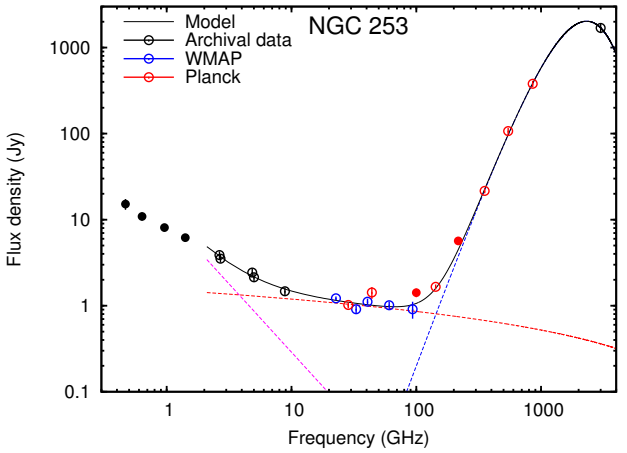
NGC 6946



(Murphy et al. 2010, Scaife et al. 2010, Hensley et al. 2015)



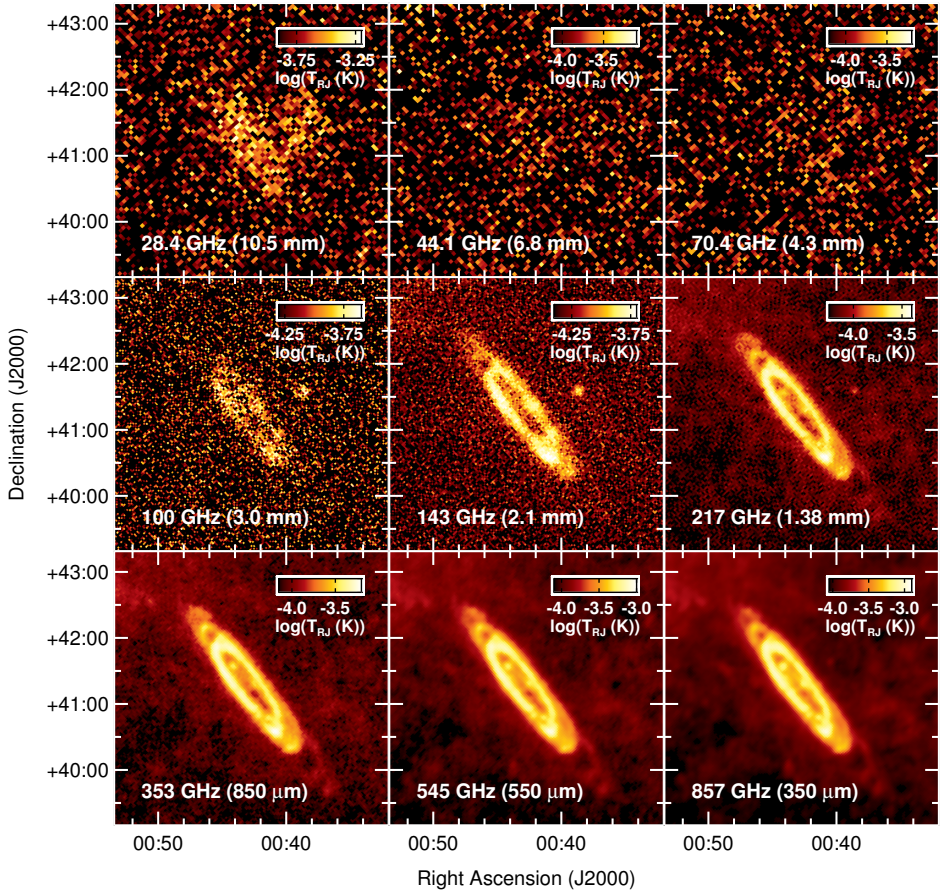


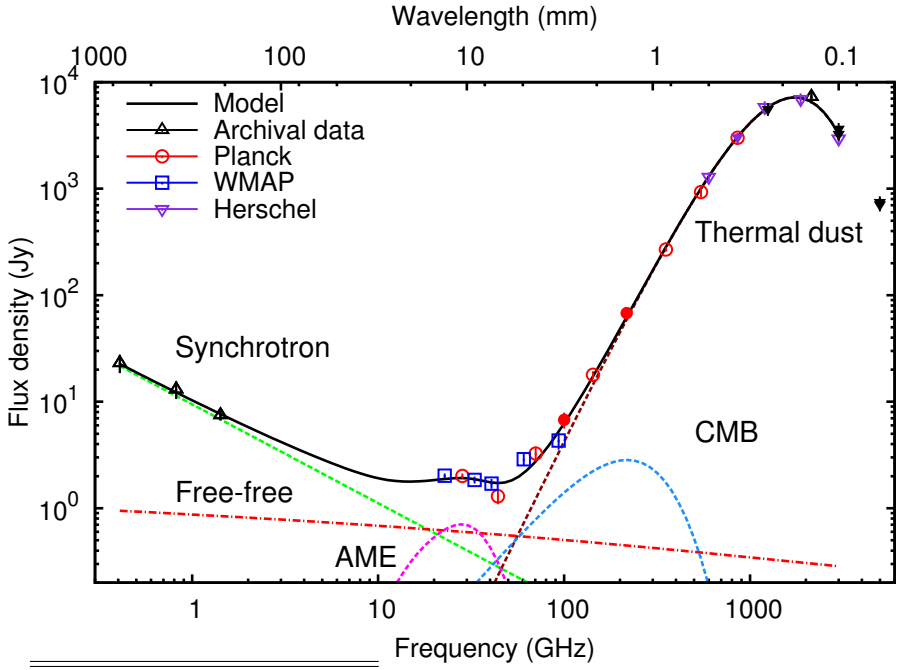


Radio to infrared spectra of late-type galaxies with Planck and WMAP data. MNRAS Letters, 416, 99, arXiv: 1105.6336

PIP XXV: Andromeda Galaxy

Planck intermediate results. XXV.
The Andromeda Galaxy as seen by Planck
A&A, 582, A28, arXiv: 1407.5452

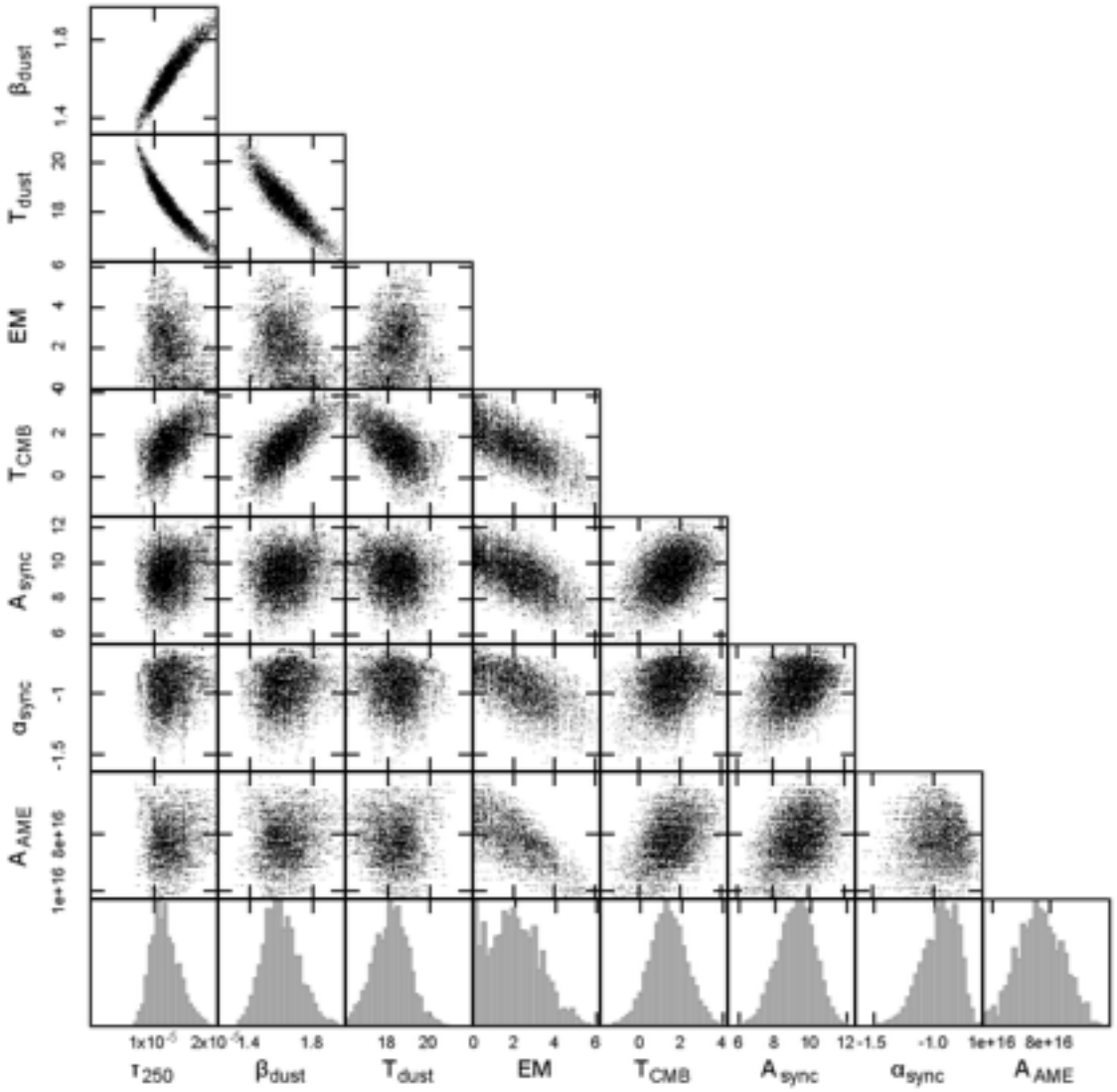




Parameter	Value
τ_{250}	$(1.2 \pm 0.2) \times 10^{-5}$
$\beta_{\rm dust}$	1.62 ± 0.11
$T_{\rm dust}$ [K]	18.2 ± 1.0
EM [cm^{-6} pc]	1.8 ± 1.3
$\Delta T_{\rm CMB}$ [K]	$(1.7 \pm 1.0) \times 10^{-6}$
$A_{\rm synch}$ [Jy]	9.5 ± 1.1
$\alpha_{\rm synch}$	-0.92 ± 0.16
$A_{\rm AME}$ [Sr cm^{-2}]	$(7.7 \pm 3.3) \times 10^{16}$
χ^2	15.4
$N_{\rm dof}$	14

2.3σ

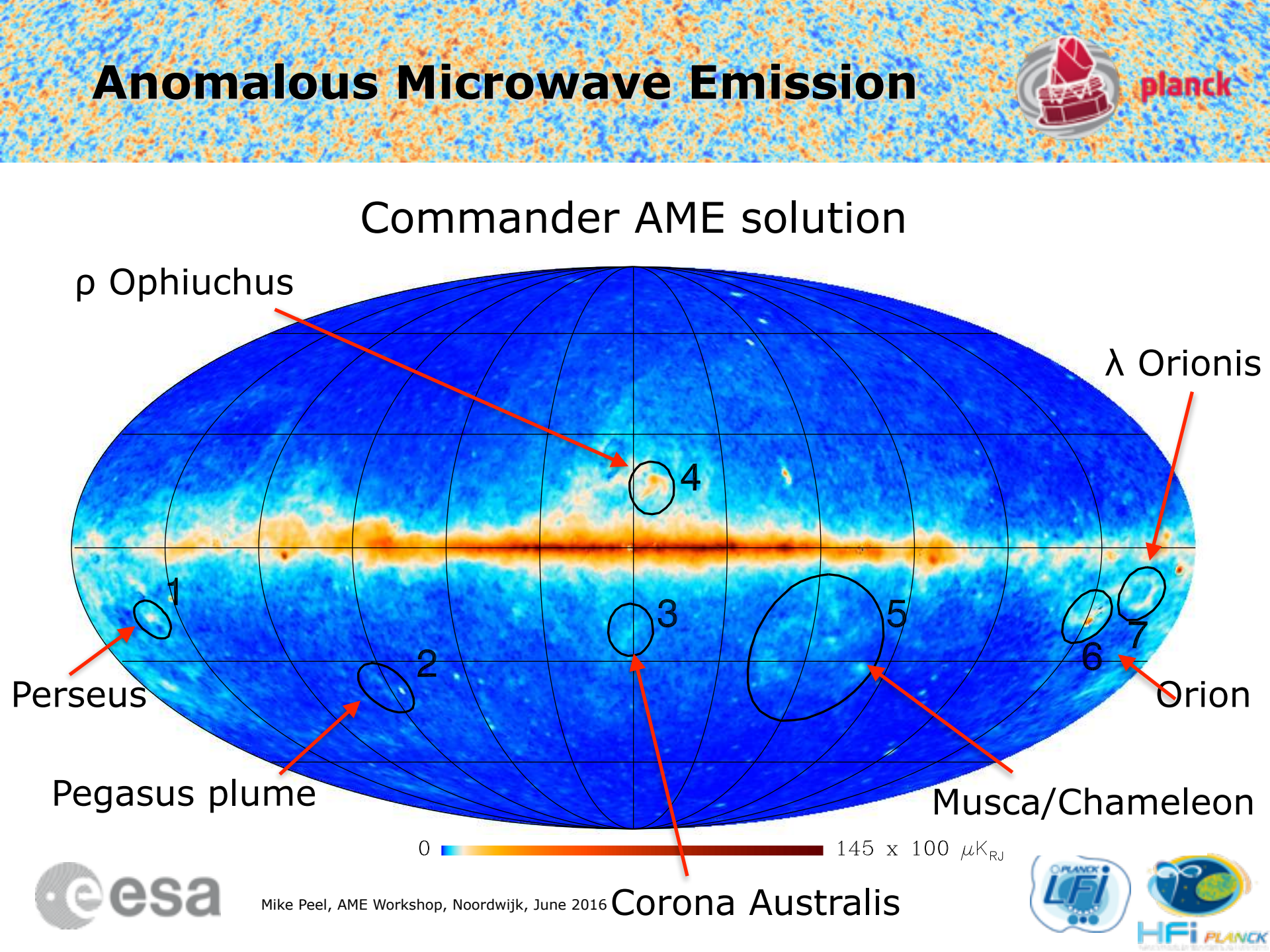
PIP XXV: Andromeda Galaxy



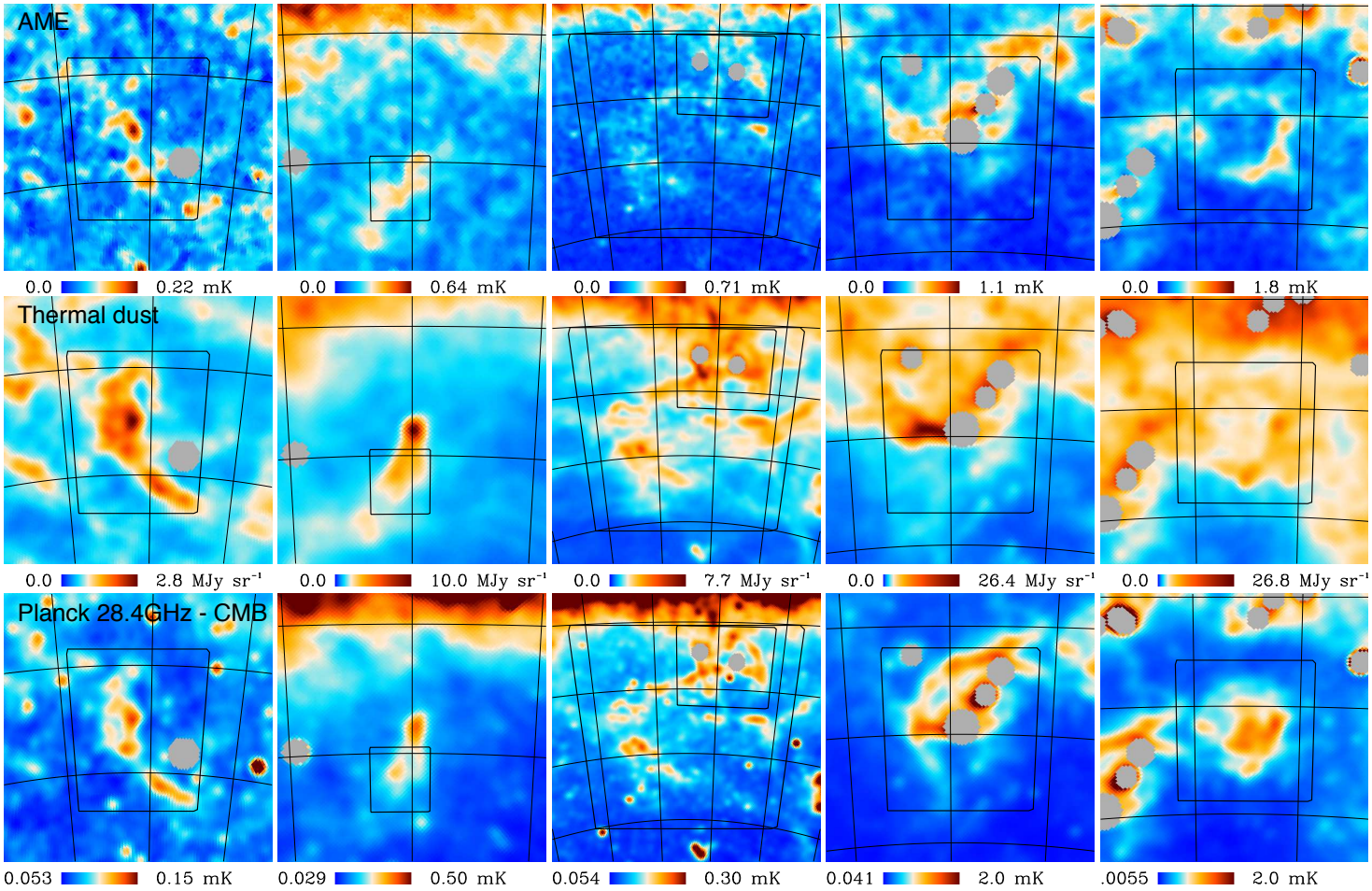
Commander component maps

- Component separation mostly focuses on CMB maps, having e.g., a single low-frequency component. (see Planck Col. 2015. IX.)
- Commander: Bayesian technique, separate components using frequency information (see Eriksen et al. 2008)
- Thanks to many maps from Planck+WMAP+Haslam, we can separate:
    - Synchrotron (but fixed spectral index)
    - Free-free (EM & T_e)
    - AME (two spinning dust components combined)
    - Thermal dust (only fitting up to 857GHz)
    - + CMB, CO, HCN, calibration factors, bandpass shifts; described in Planck Col. 2015. X.
- Also: high S/N synchrotron polarization map. Combined Planck & WMAP data (weighted, mostly WMAP K & Planck 30).

Anomalous Microwave Emission

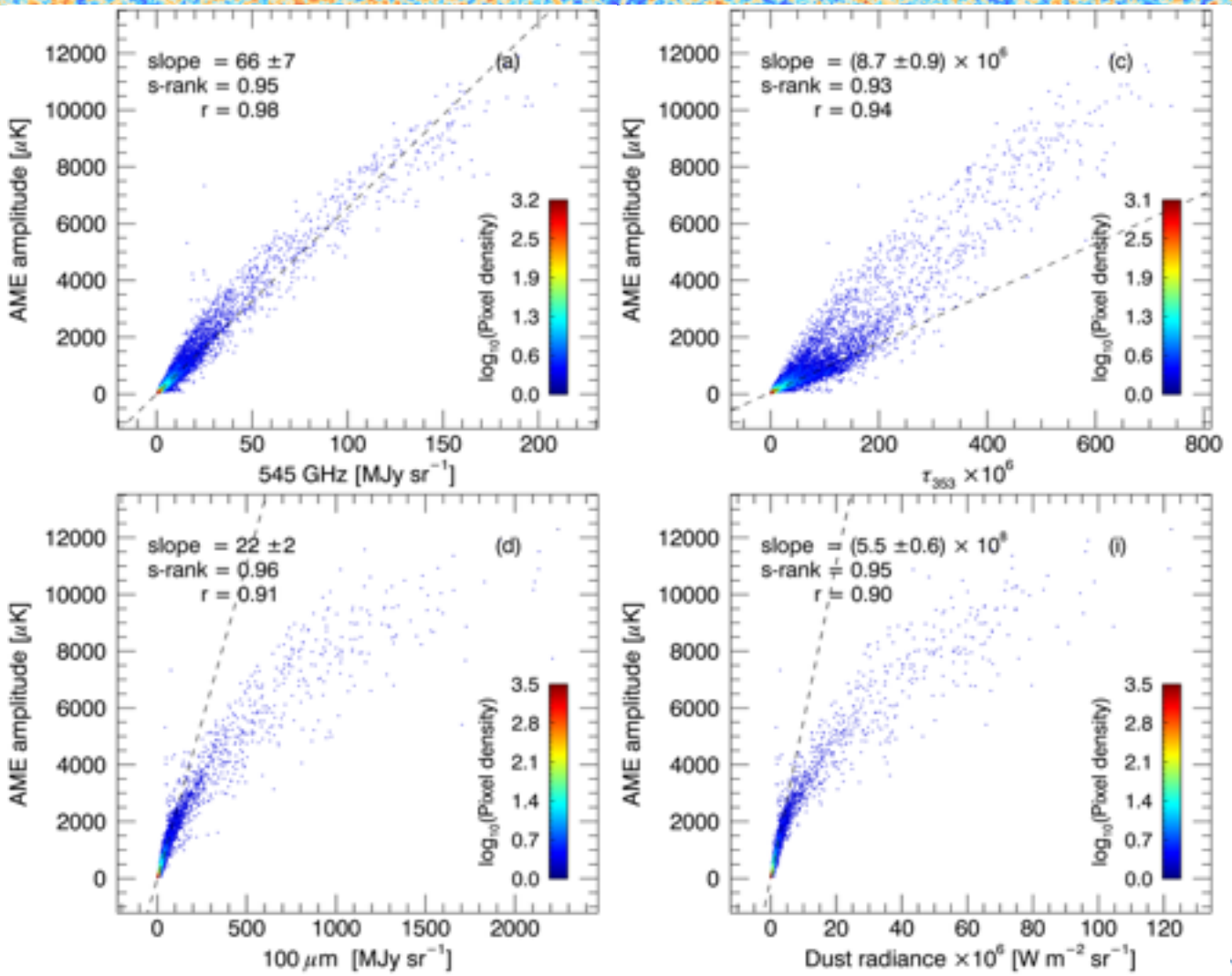


New AME regions



Pegasus plume | Corona Australis | Musca/ Chameleon | Orion | λ Orionis

AME correlations



Emissivities

Emissivities against 545/τ_{353} appear to vary by factor of 2

Very high emissivity in λ Orionis (Also Chamaeleon)

Good agreement with previous emissivities (e.g., Davies et al.)

Region	AME/545 GHz [μK (MJy sr^{-1})$^{-1}$]	AME/100 μm [μK (MJy sr^{-1})$^{-1}$]	AME/τ_{353} [μK 10^{-6}]
R1: Perseus	24 ± 7	12.3 ± 1.9	1.5 ± 0.9
R2: Plume	47 ± 6	18 ± 2	7.7 ± 1.0
R3: R CrA	36 ± 14	50 ± 12	4.1 ± 1.8
R4: ρ Oph	40 ± 9	4.6 ± 0.9	2.2 ± 1.2
R5: Musca	59 ± 8	26 ± 3	6.9 ± 1.0
Chamaeleon	74 ± 8	22 ± 2	11 ± 1.1
R6: Orion	47 ± 5	20 ± 2	4.7 ± 0.6
R7: λ Orionis	104 ± 11	25 ± 3	15 ± 1.8
Entire sky	65 ± 7	22 ± 2	8.3 ± 0.8
$\|b\| > 10°$	70 ± 7	21 ± 2	9.7 ± 1.0
XV: Perseus	...	24 ± 4	...
XV: ρ Oph	...	8.3 ± 1.1	...
XV: Mean	...	32 ± 4	...
D06: Kp2 mask	...	21.8 ± 1.0	...
D06: Region mean	...	25.7 ± 1.3	...

High-frequency peakers

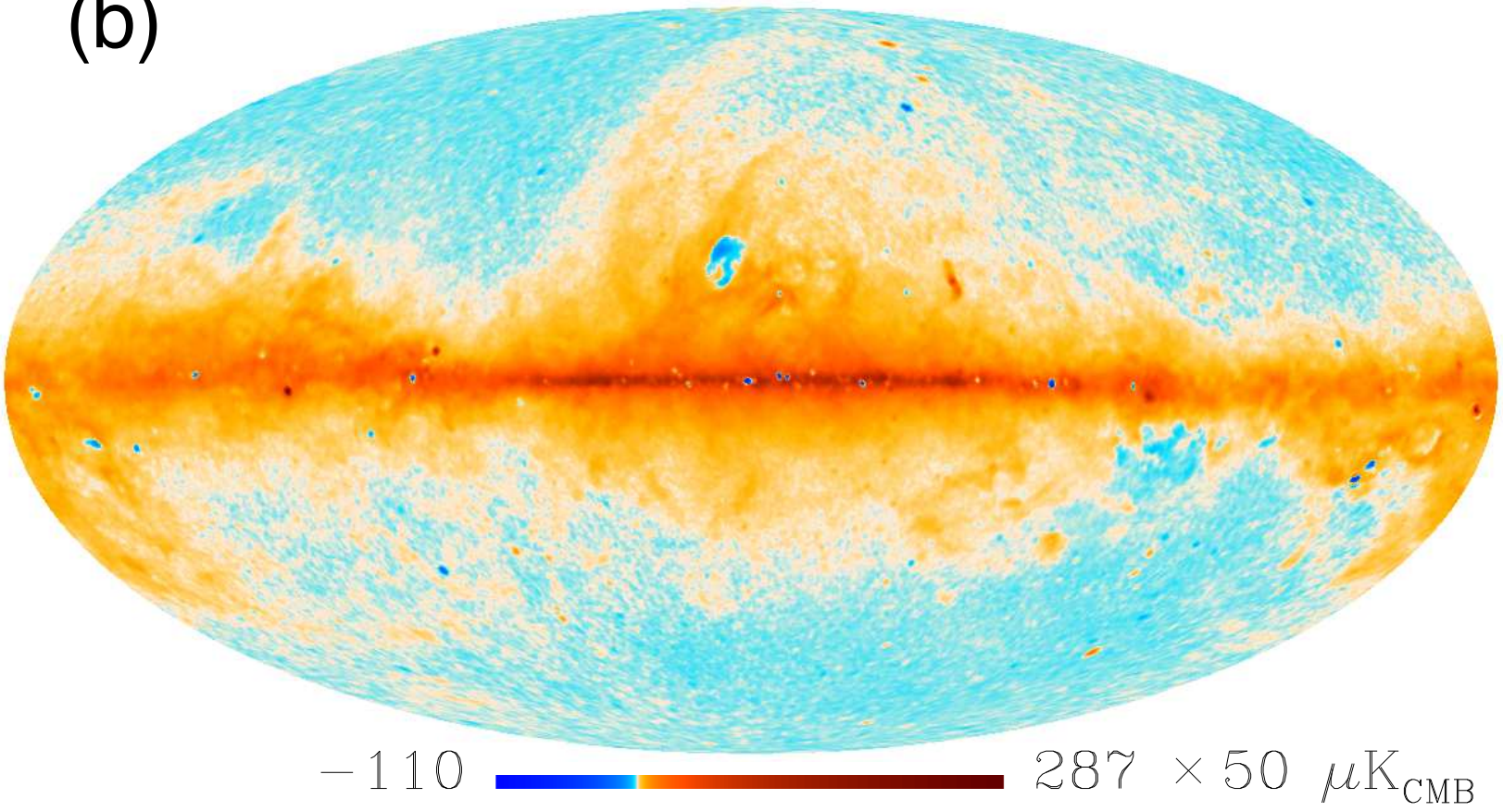
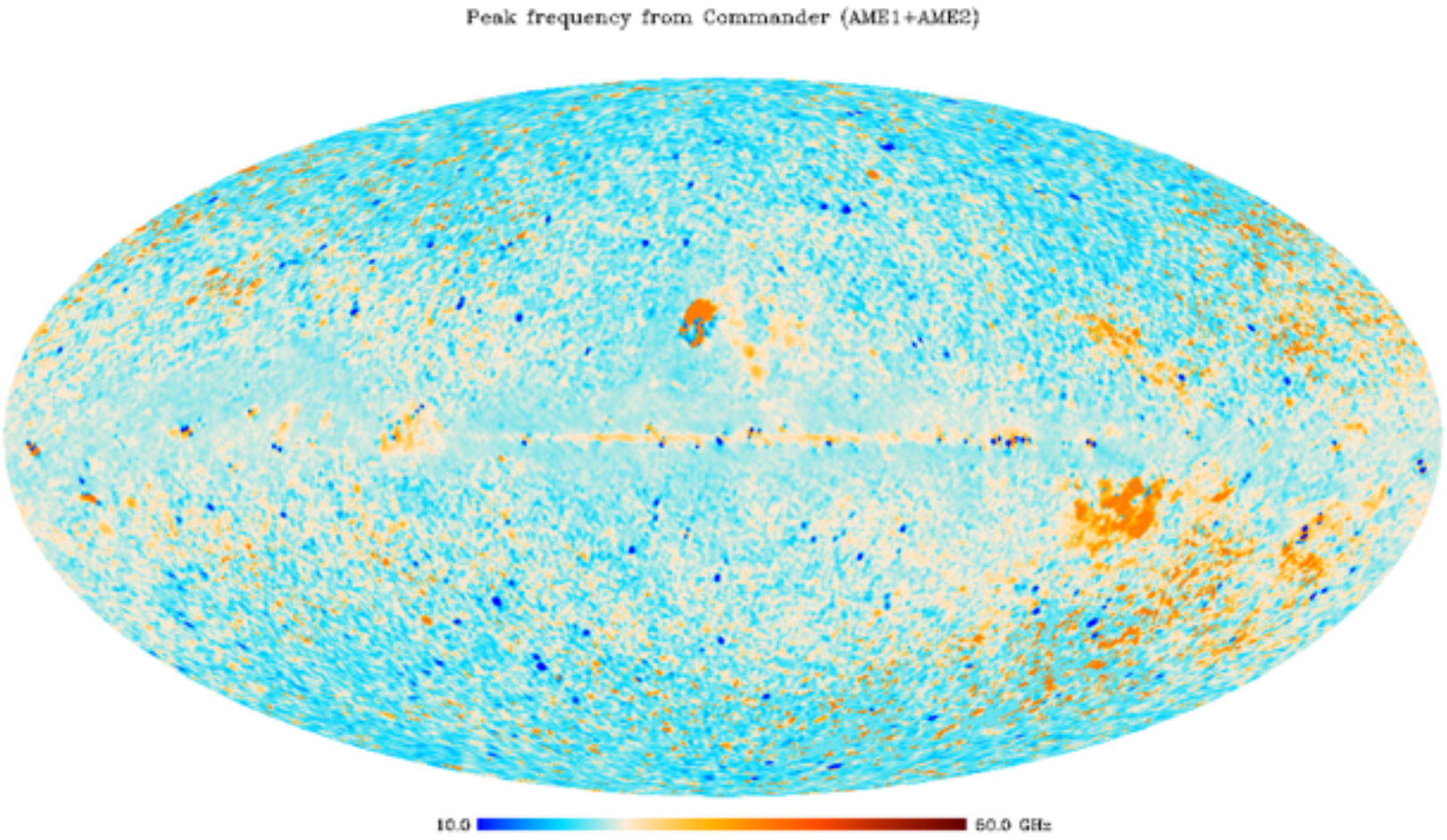


Fig 3b from Planck 2016 XXV. ILC with CMB, free-free and thermal dust nulled.

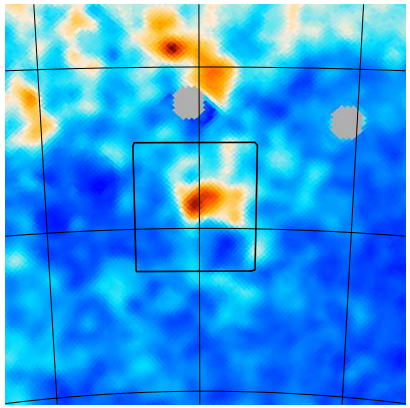
High-frequency peakers

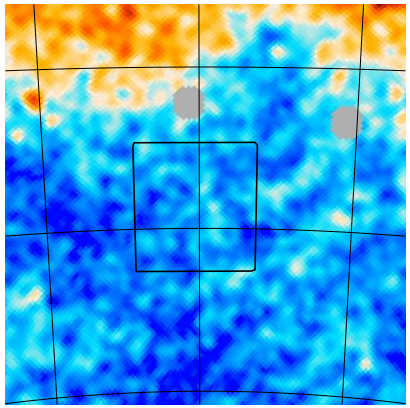


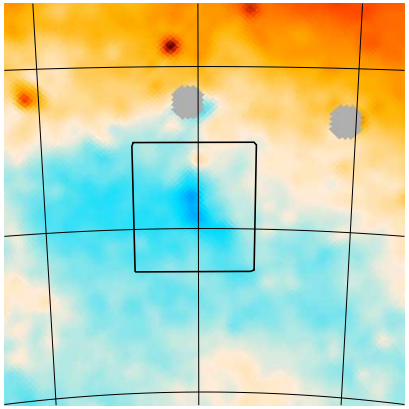
Combined peak frequency from the two AME components fitted by Commander

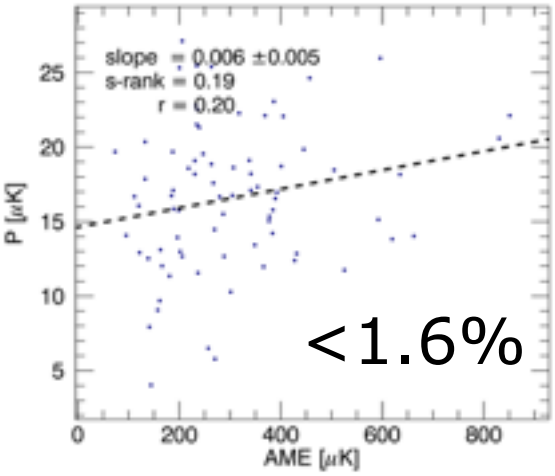
AME polarization

Perseus

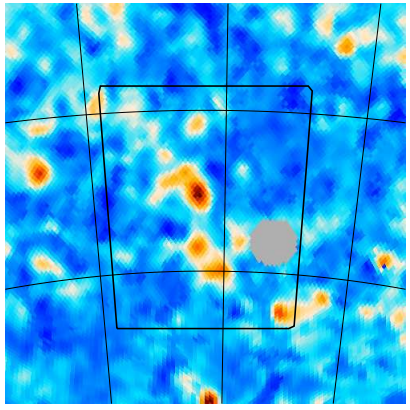


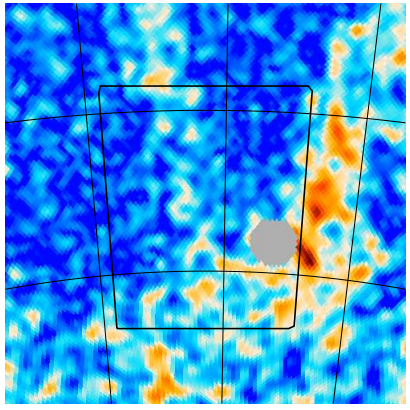


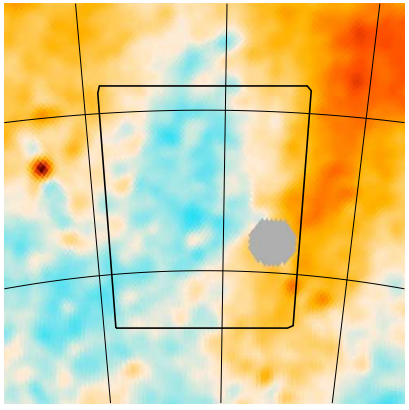


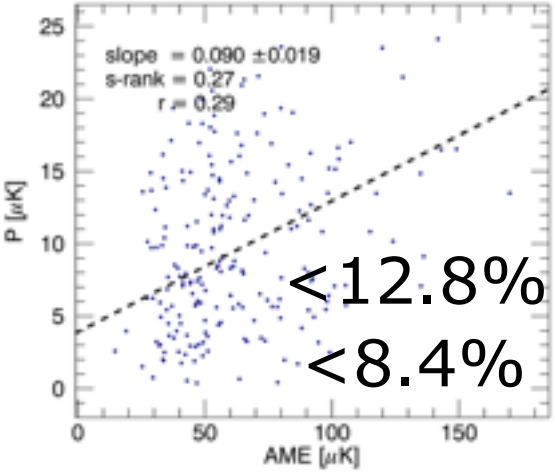


Plume



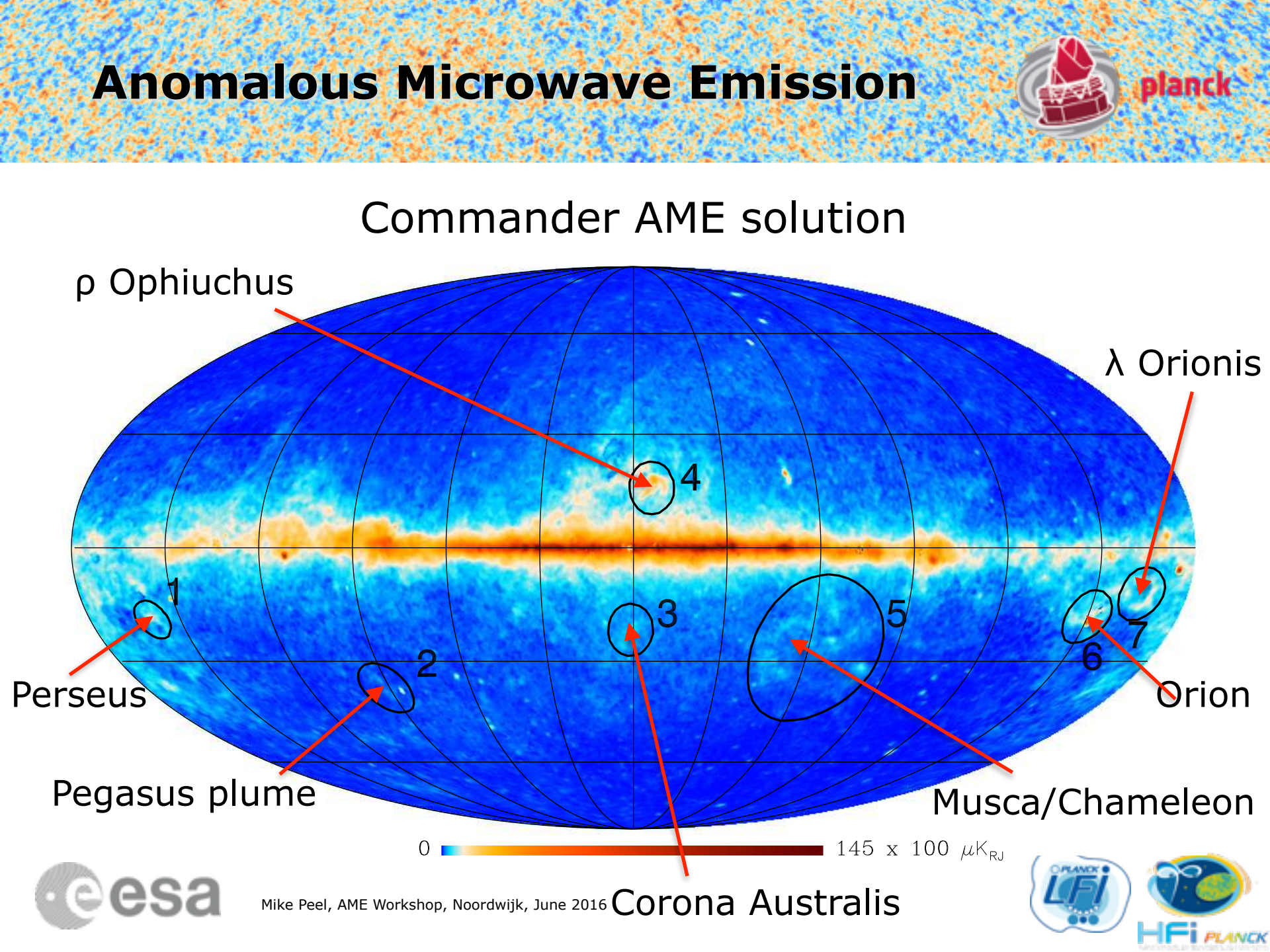




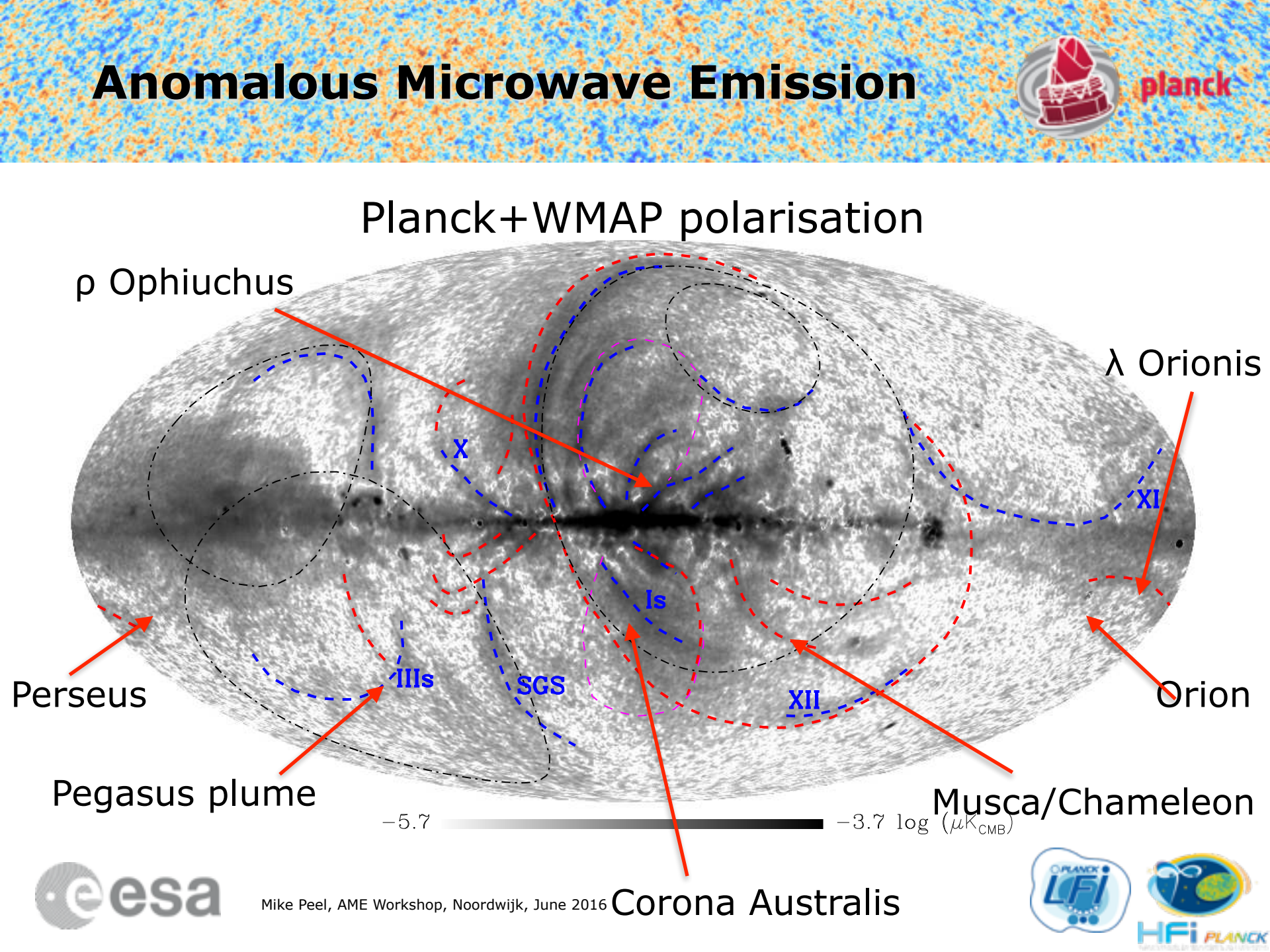


Spinning dust models predict low polarization fractions.

Anomalous Microwave Emission



Anomalous Microwave Emission



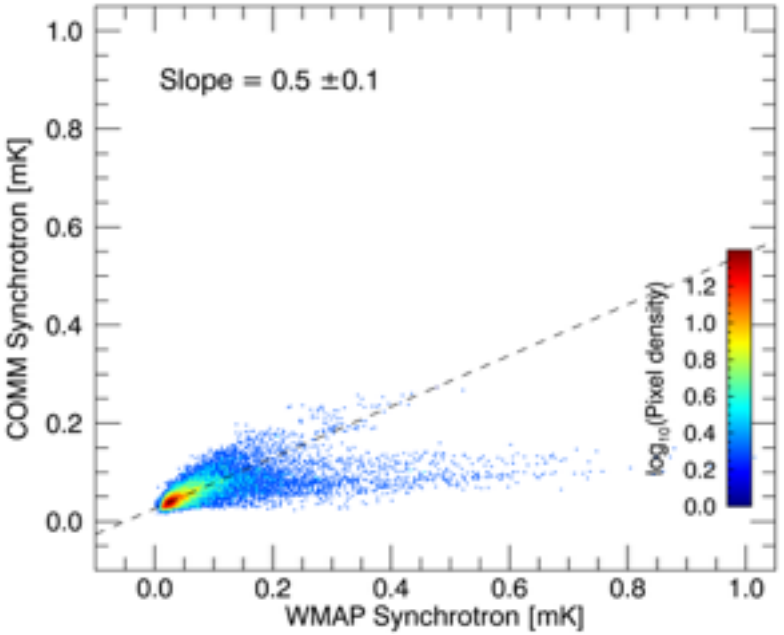
Comparison with WMAP

Run	Sync		Free-free		AME	
	a	*r*	*a*	*r*	*a*	*r*
MCMC-c base	0.50	0.62	0.68	0.77	...	...
MCMC-e sdcnm	0.52	0.92	0.77	0.87	4.91	0.75
MCMC-f fs	0.52	0.62	0.80	0.77	3.18	0.67
MCMC-g fss	0.55	0.62	0.77	0.78	3.14	0.70
MEM	0.34	0.84	0.76	0.79	2.18	0.86

|b| > 20°

a>1 = commander > WMAP

Trust values if r≳0.9



AME systematically higher
Free-free about the same
Synchrotron lower

Synchrotron is not 1:1 - two populations due to spectral indices

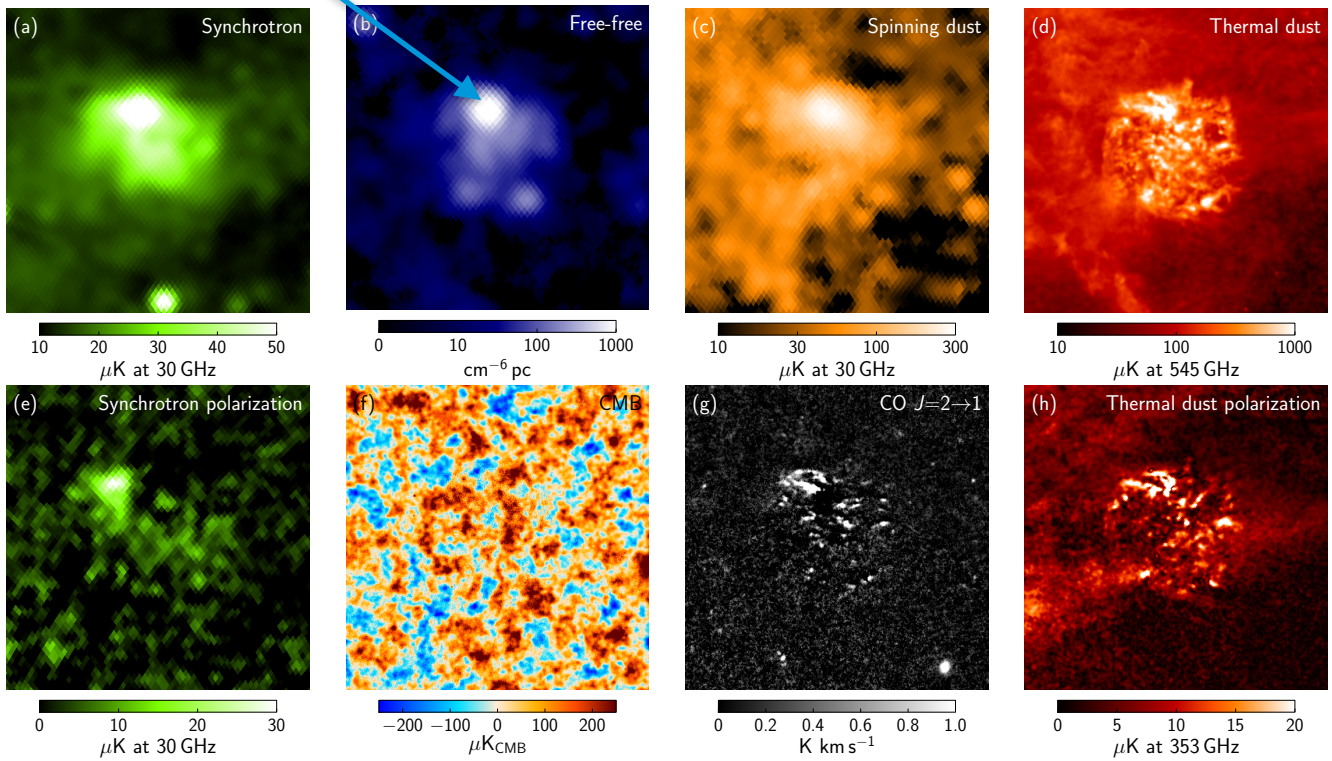
Large Magellanic Cloud

30 Dor

Dominates SED

AME emissivities comparable to our Galaxy (except 100um)

Could be too steep?

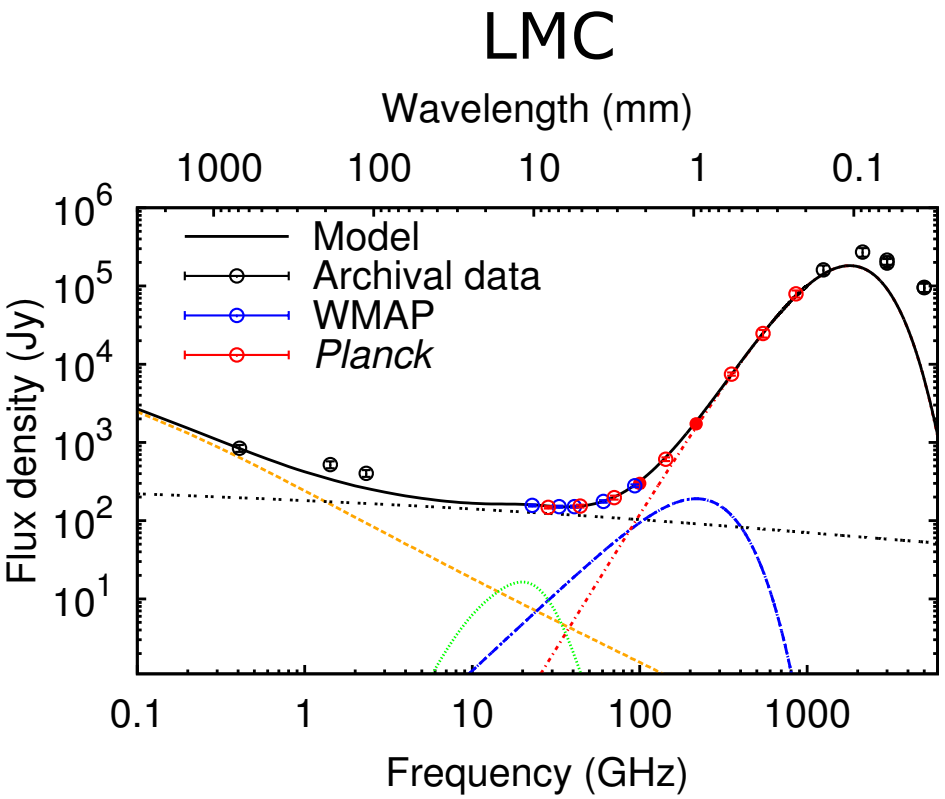


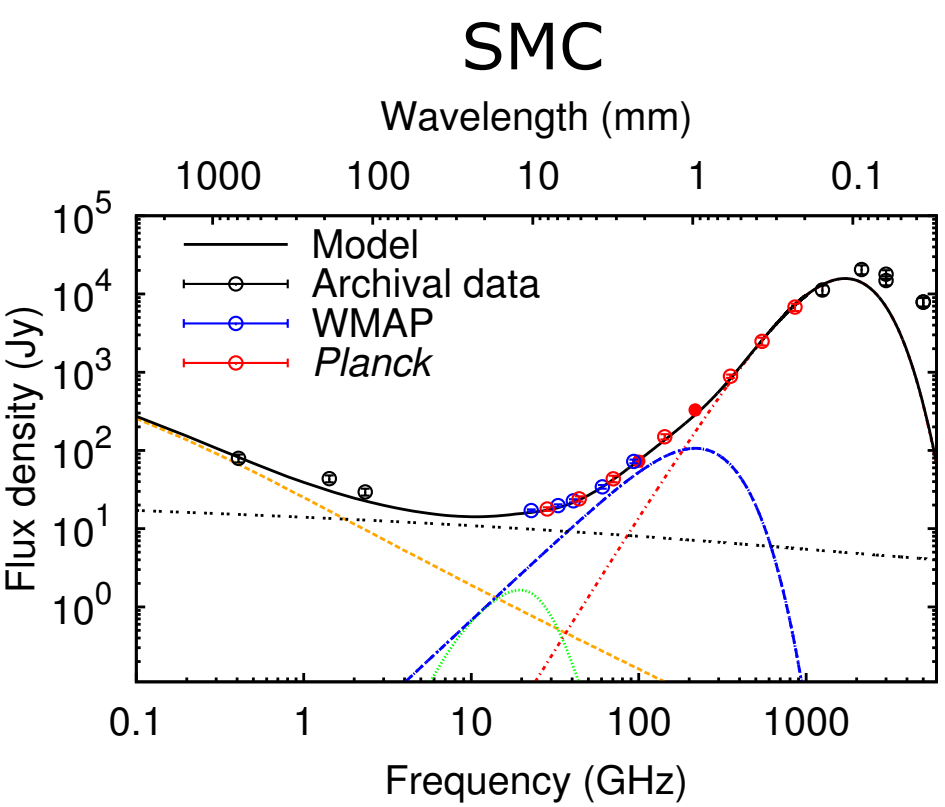
Up to 30% pol.

Clean CMB map

Good agreement with ground-based surveys

Large & Small Magellanic Clouds





AME <~0.2Jy

c.f. 3-5Jy from Hensley

Conclusions

1. Commander has done a relatively clean separation of Planck & WMAP data into synchrotron, free-free, AME & thermal dust emission (+CO, HCN)
2. AME emission seems best correlated with thermal dust at 545GHz.
3. New diffuse AME regions identified, λ Orionis particularly interesting.
4. Upper limit on pol. AME of 1.6%: need better pol. synchrotron maps!
5. Fixed synchrotron spectral index is a key limitation.
6. Need better data at 2-15GHz, e.g. S-PASS, C-BASS & QUIJOTE

For Commander analysis and maps, see arXiv:1502.01588
For the results presented here, see arXiv:1506.06660

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.

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Thank you