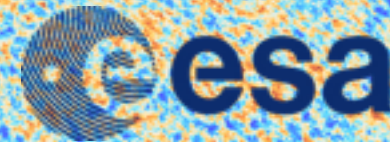




planck



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***

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1824

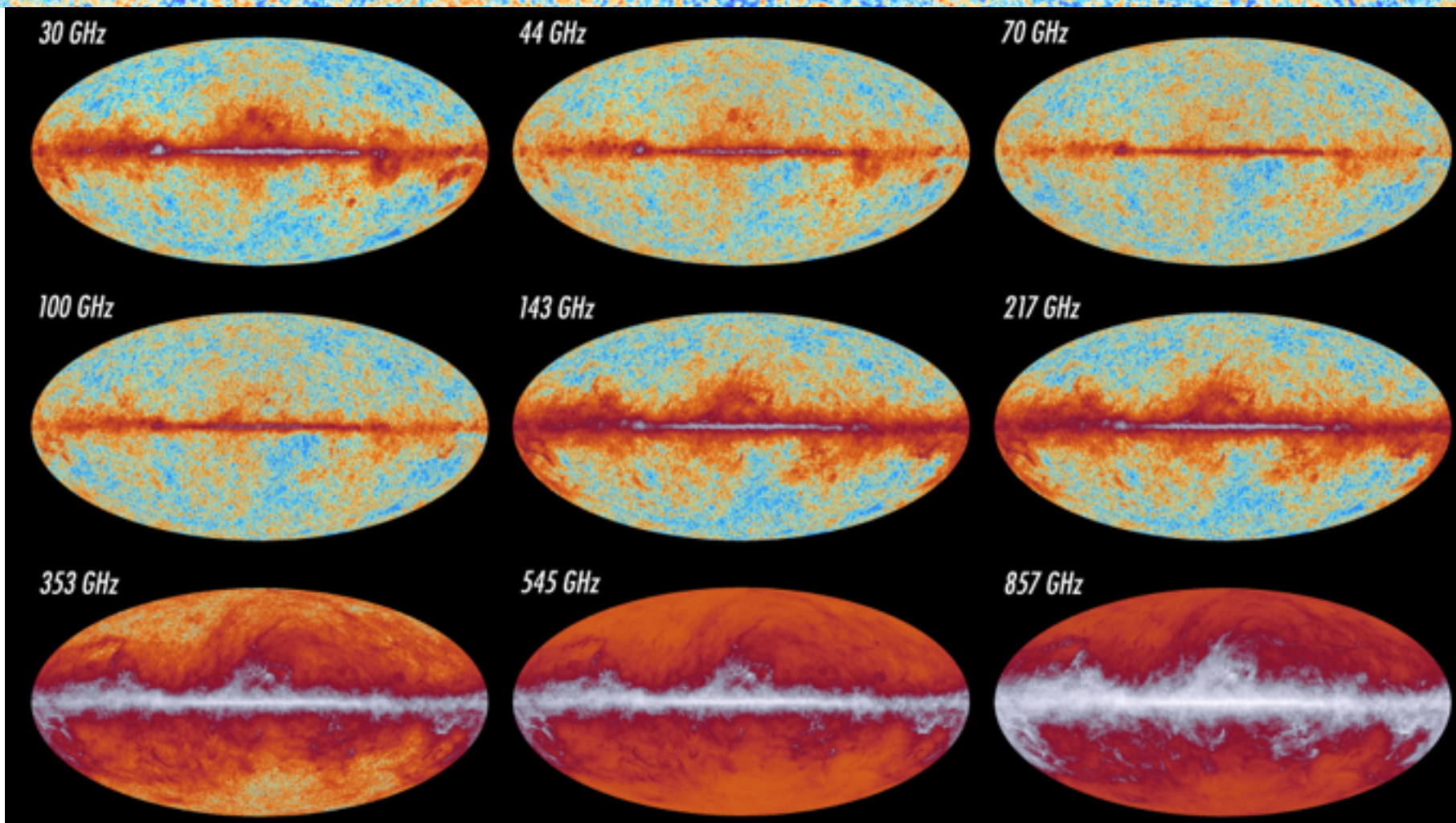
The University of Manchester



Overview



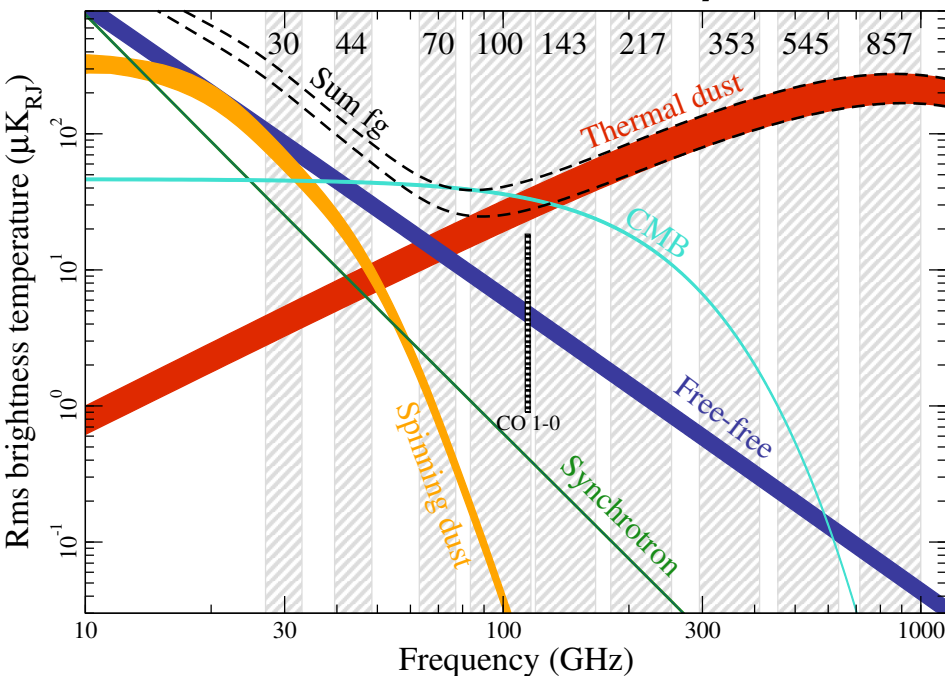
planck



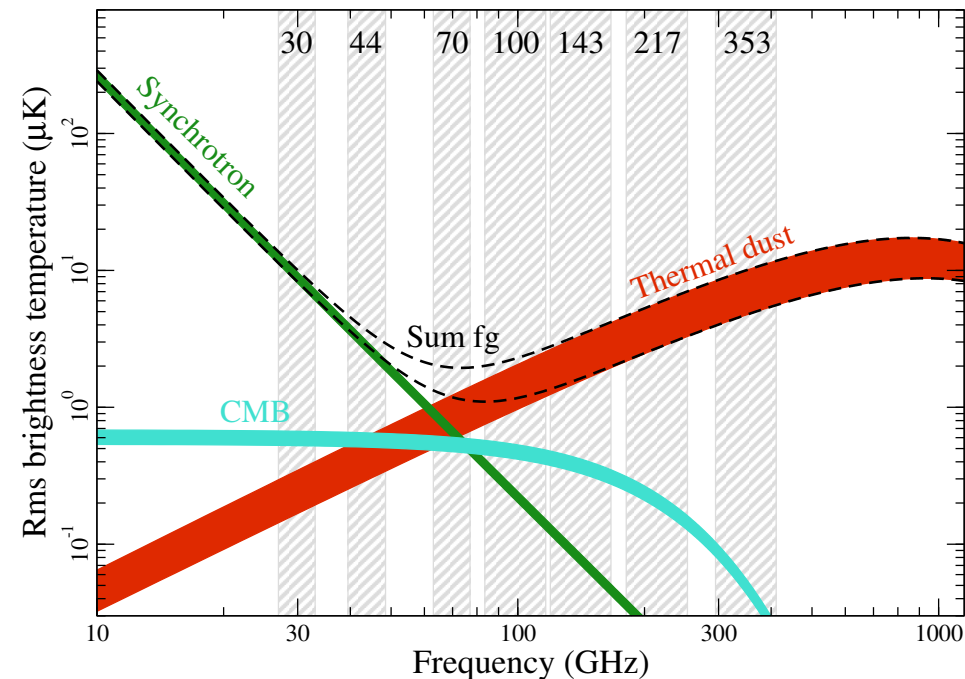
Overview



Total intensity



Polarization



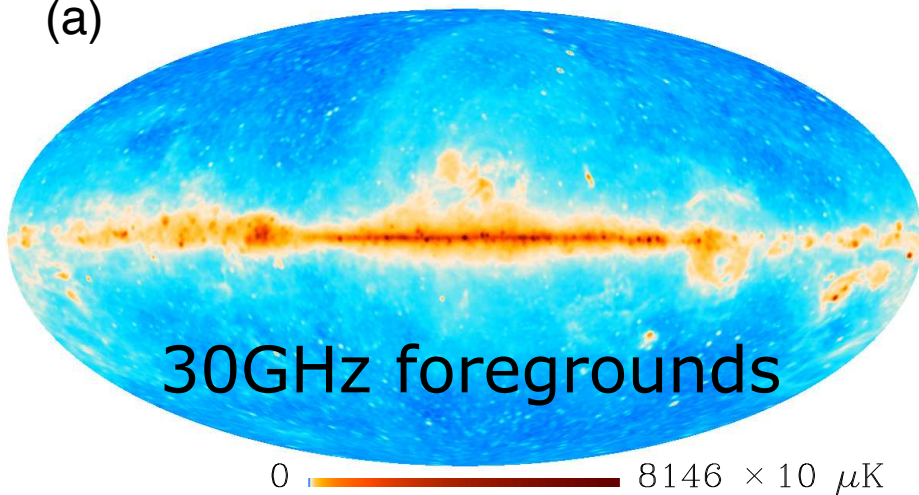
Dominated by Galactic emission at nearly every frequency.
Need to understand them well to subtract them.
Also interesting in their own right!

(Figures from Planck 2015 results. X.)

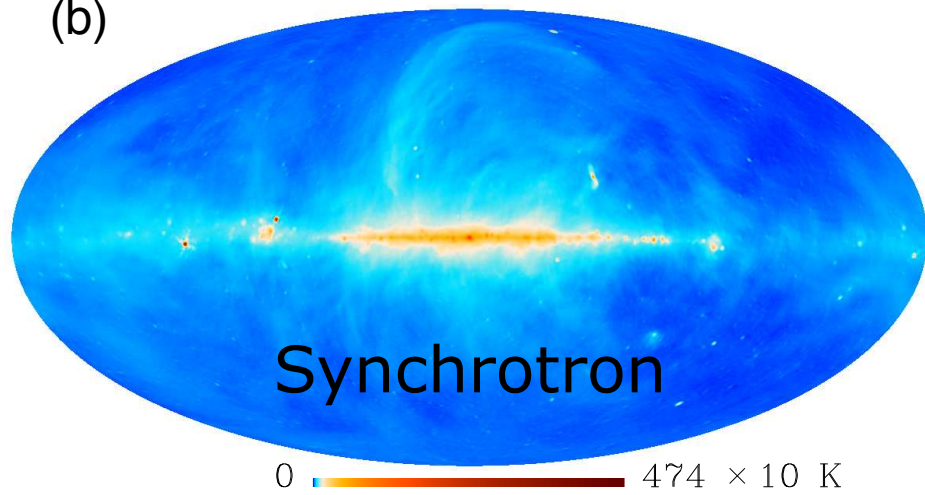
Overview



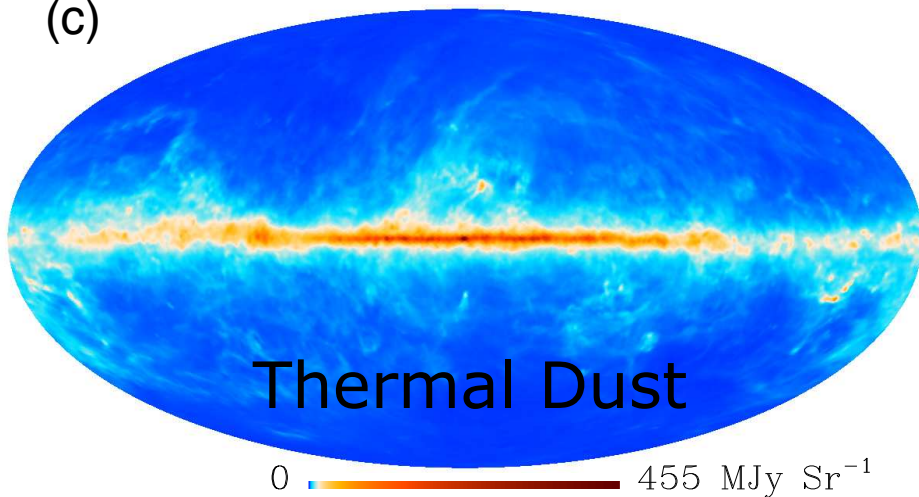
(a)



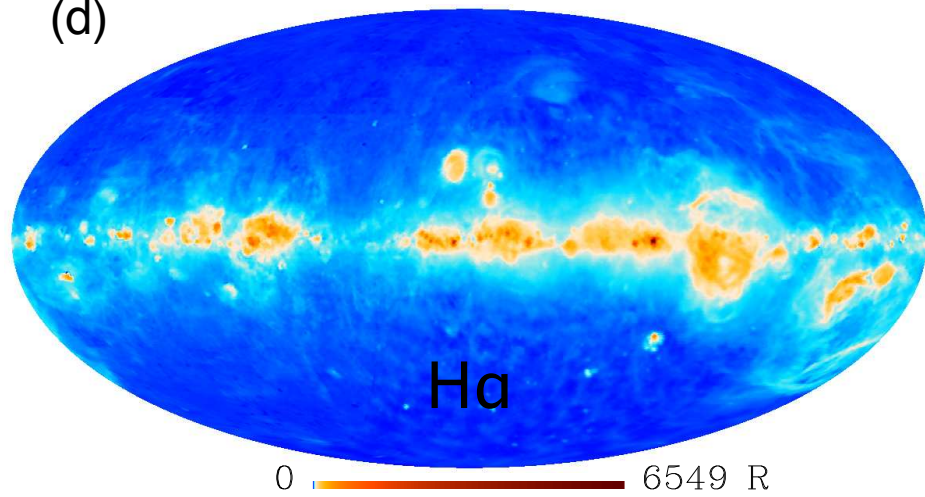
(b)



(c)

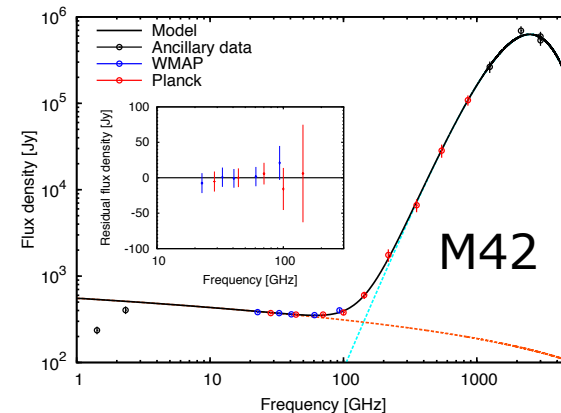
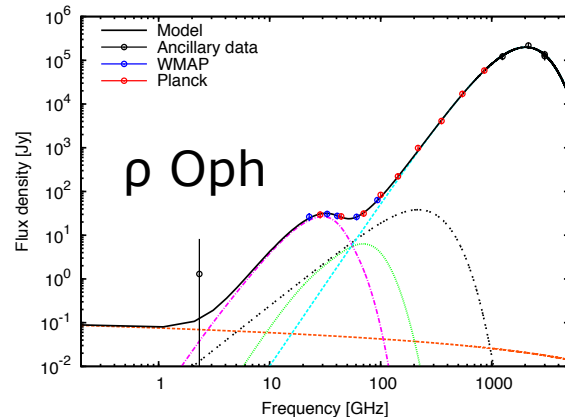
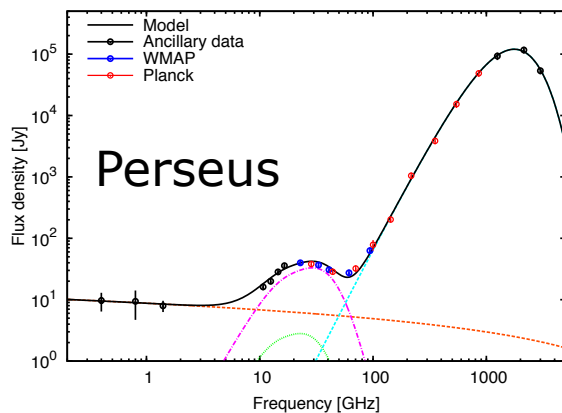


(d)



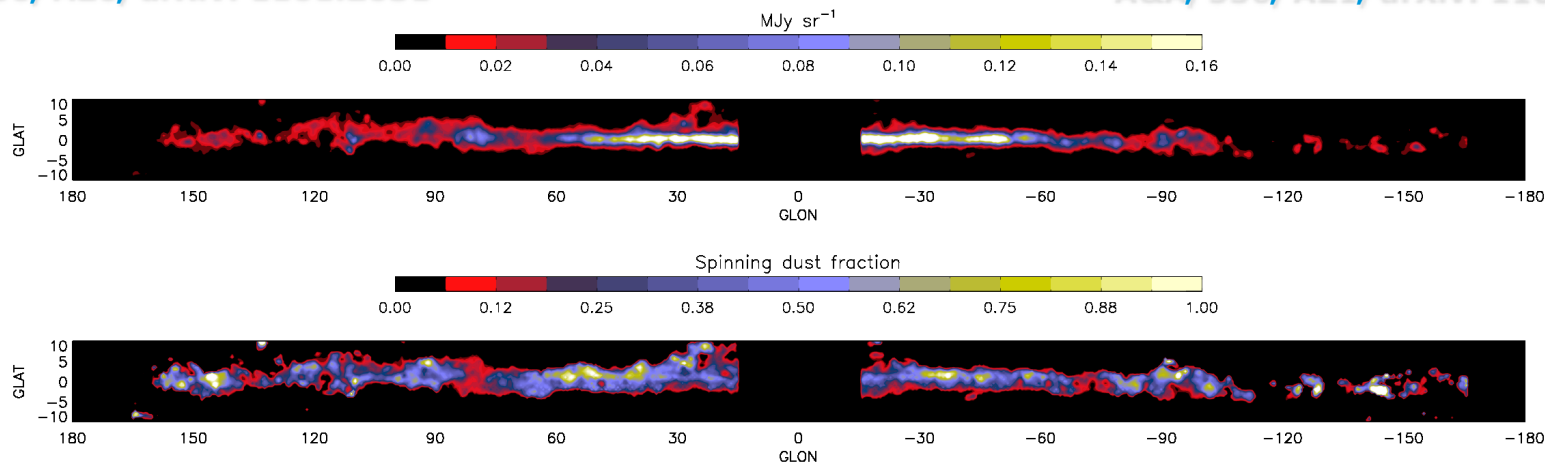
(Figures from Planck 2015 results. XXV.)

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



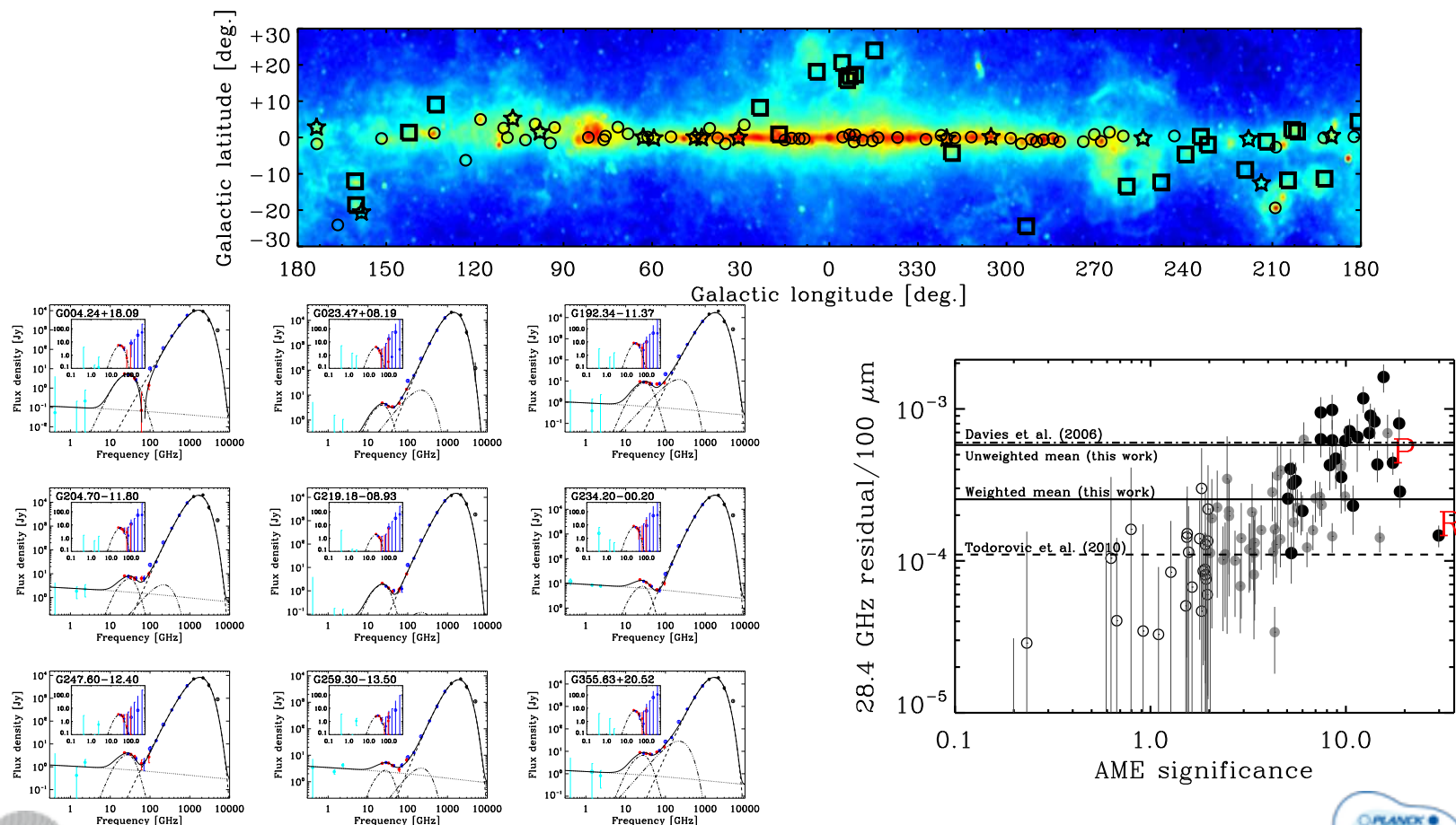
PIP XV: Planck AME study



Planck intermediate results. XV.

A study of anomalous microwave emission in Galactic clouds

A&A, 565, A103, arXiv: 1309.1357



Mike Peel, AME Workshop, Noordwijk, June 2016



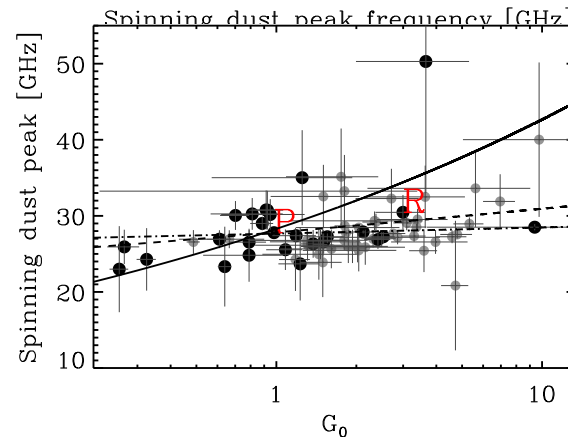
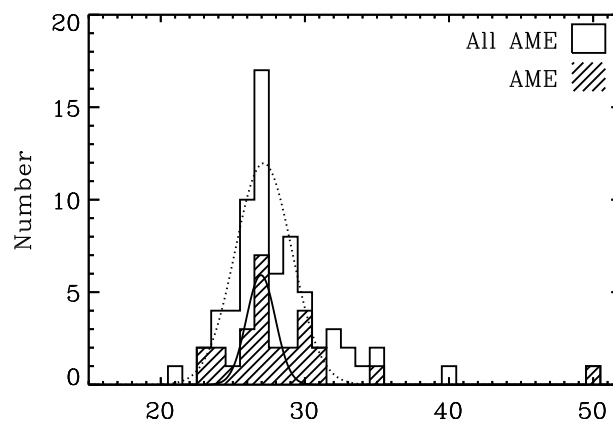
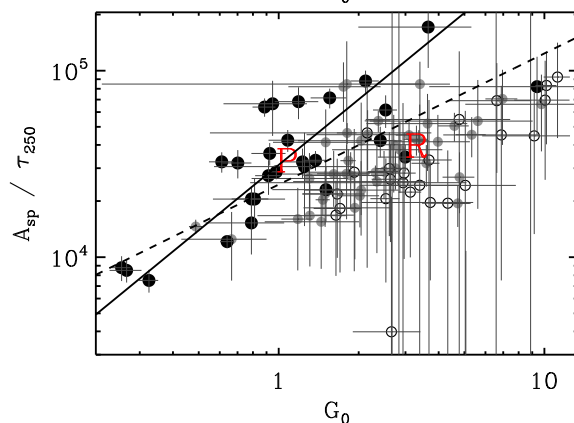
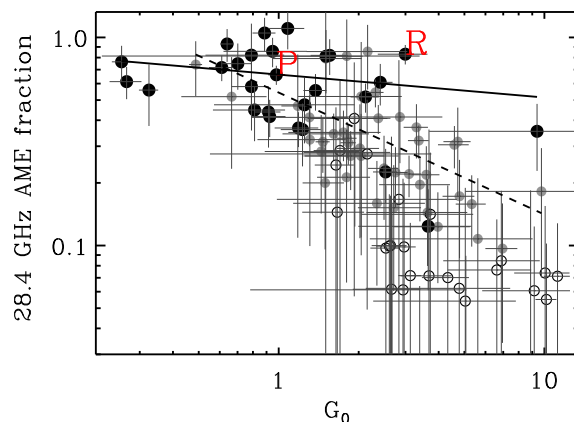
PIP XV: Planck AME study



Planck intermediate results. XV.

A study of anomalous microwave emission in Galactic clouds

A&A, 565, A103, arXiv: 1309.1357



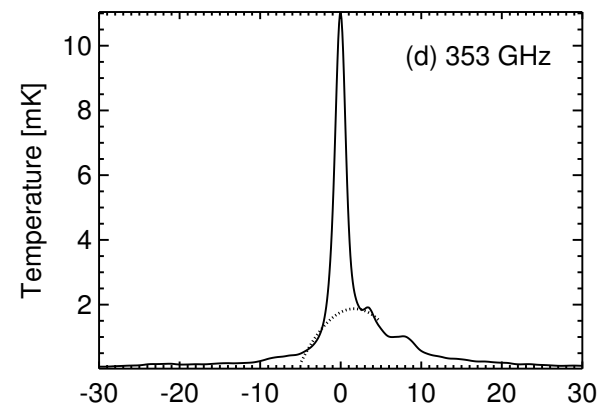
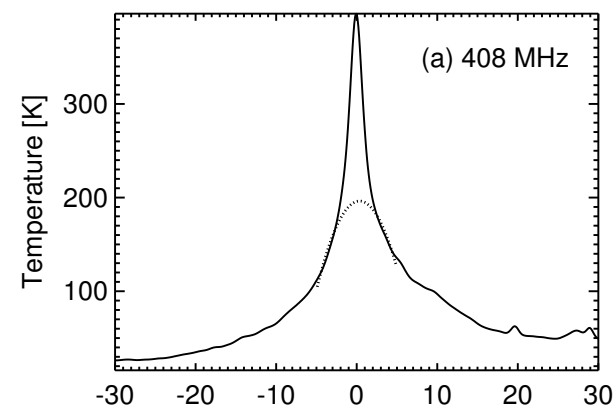
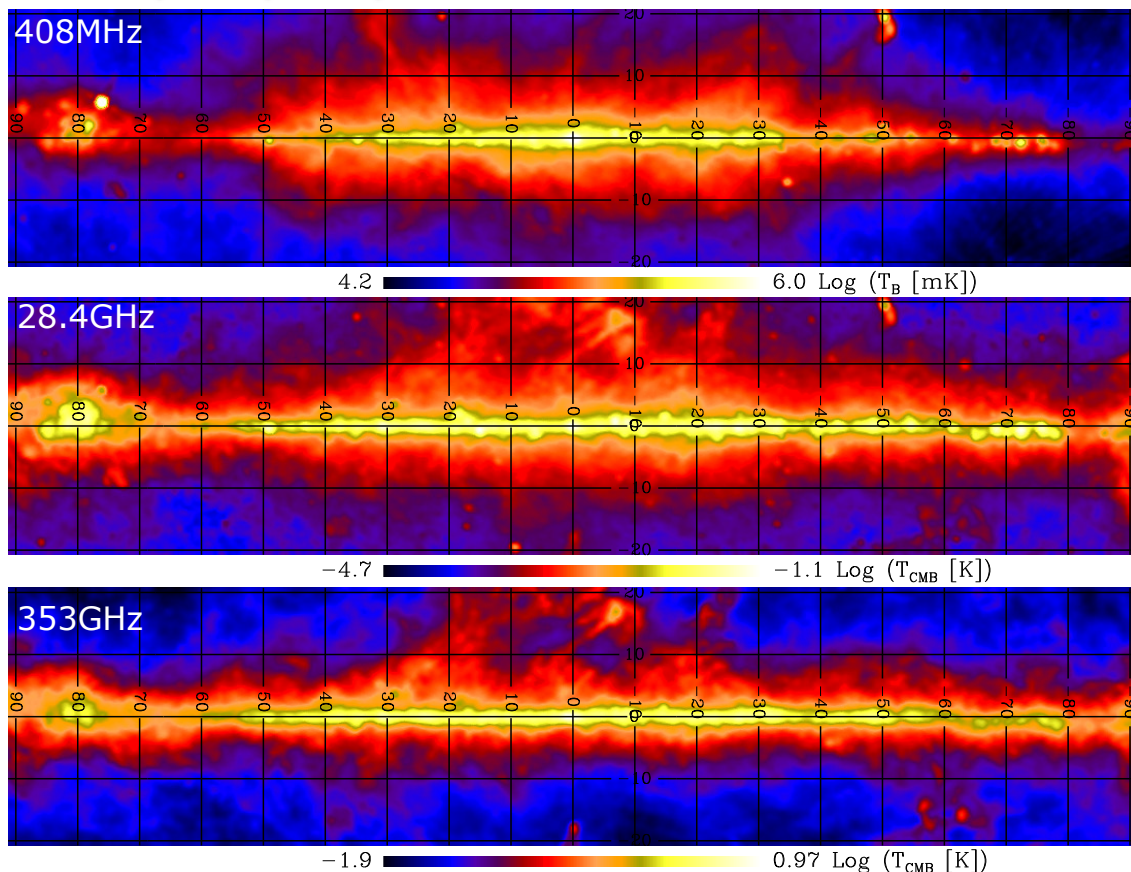
PIP XXIII: Galactic Plane



Planck intermediate results. XXIII.

Galactic plane emission components derived from Planck with ancillary data

A&A, 580, A13, arXiv: 1406.5093



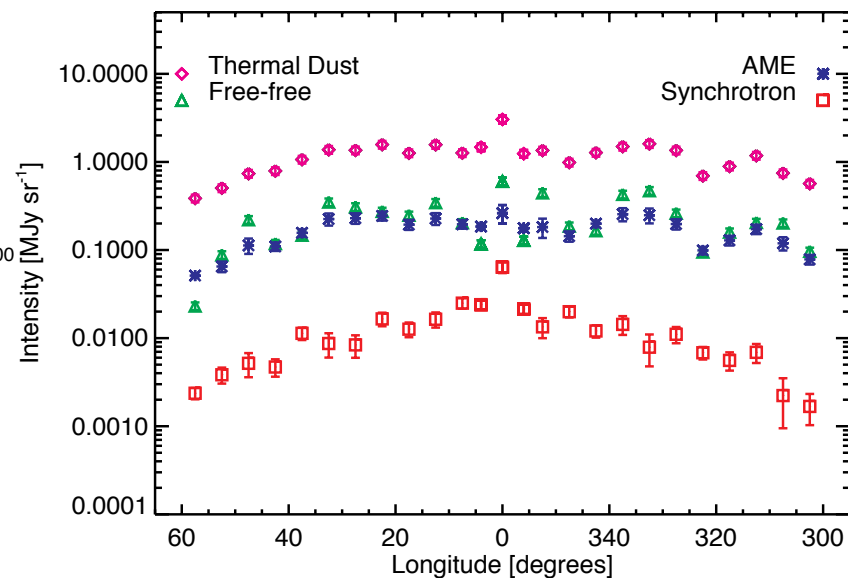
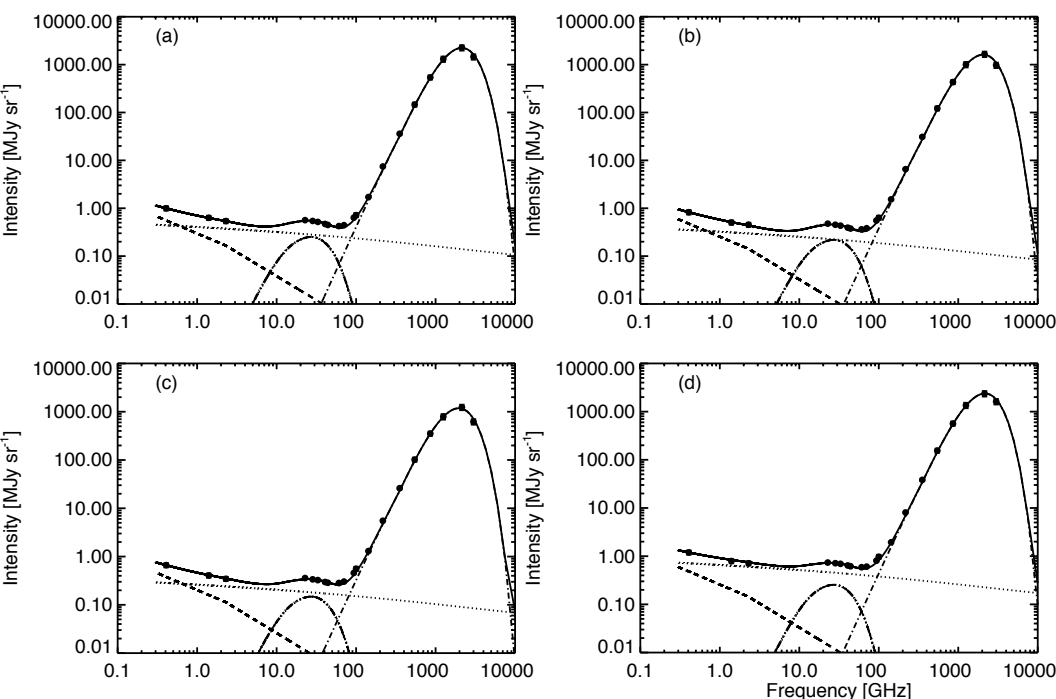
PIP XXIII: Galactic Plane



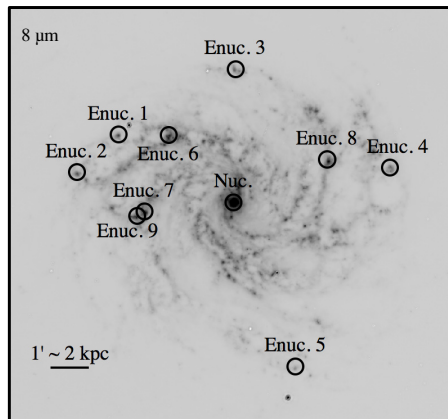
Planck intermediate results. XXIII.

Galactic plane emission components derived from Planck with ancillary data

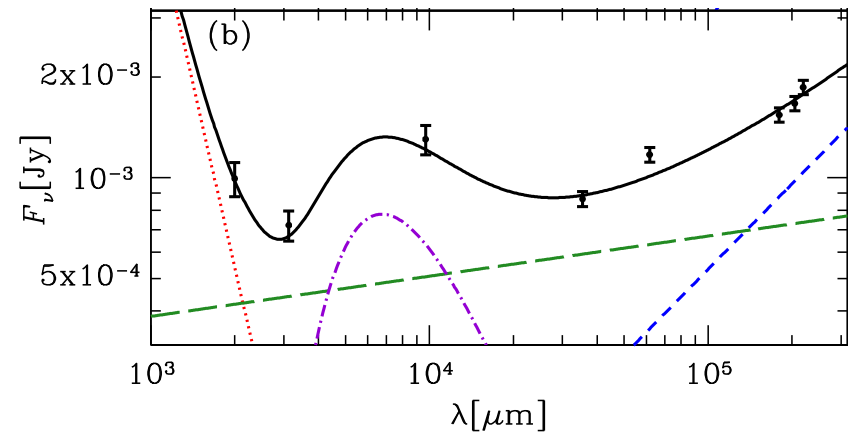
A&A, 580, A13, arXiv: 1406.5093



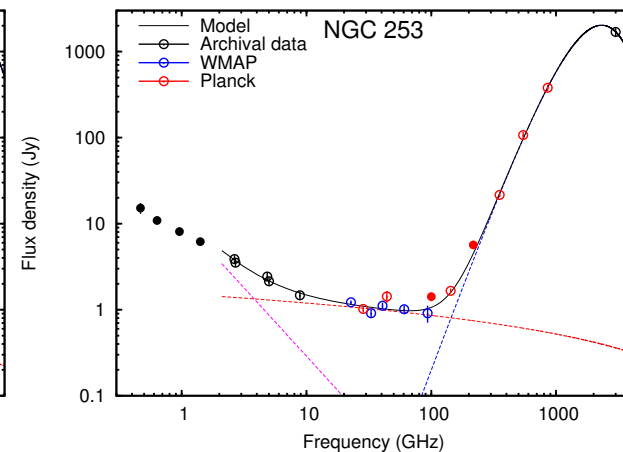
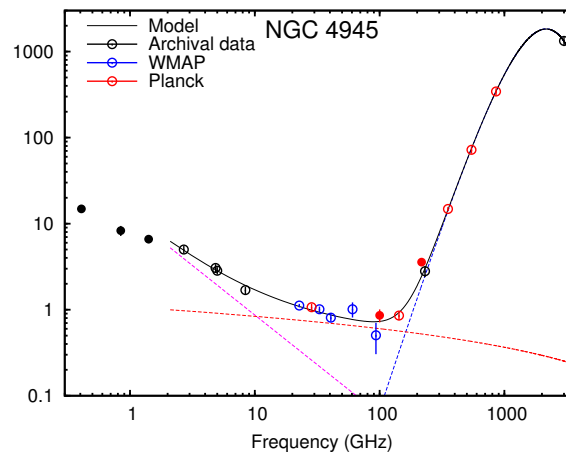
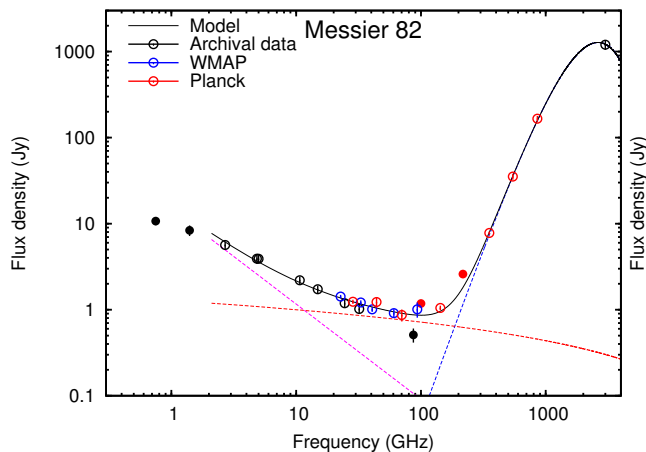
AME in nearby galaxies



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

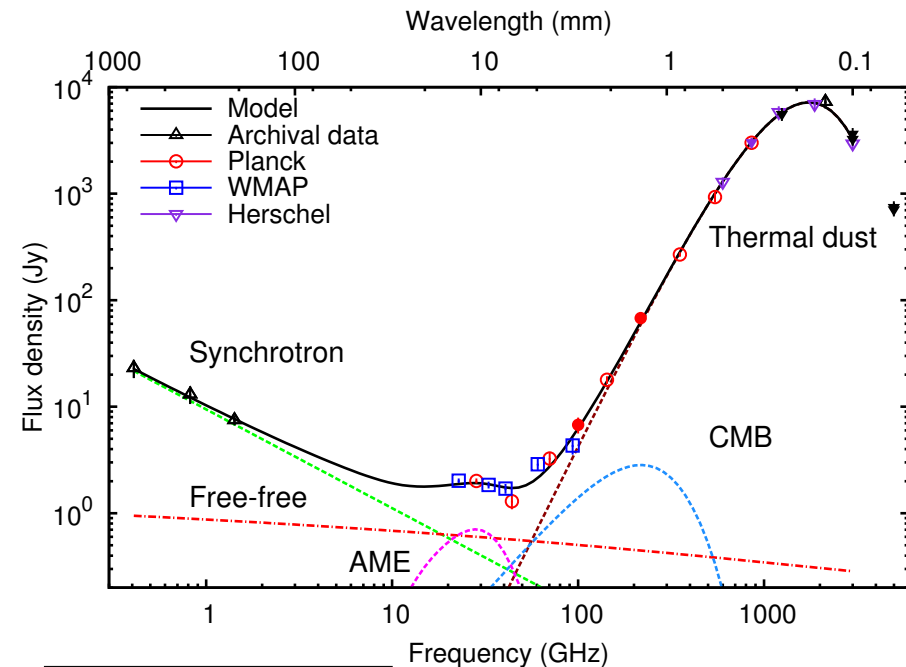
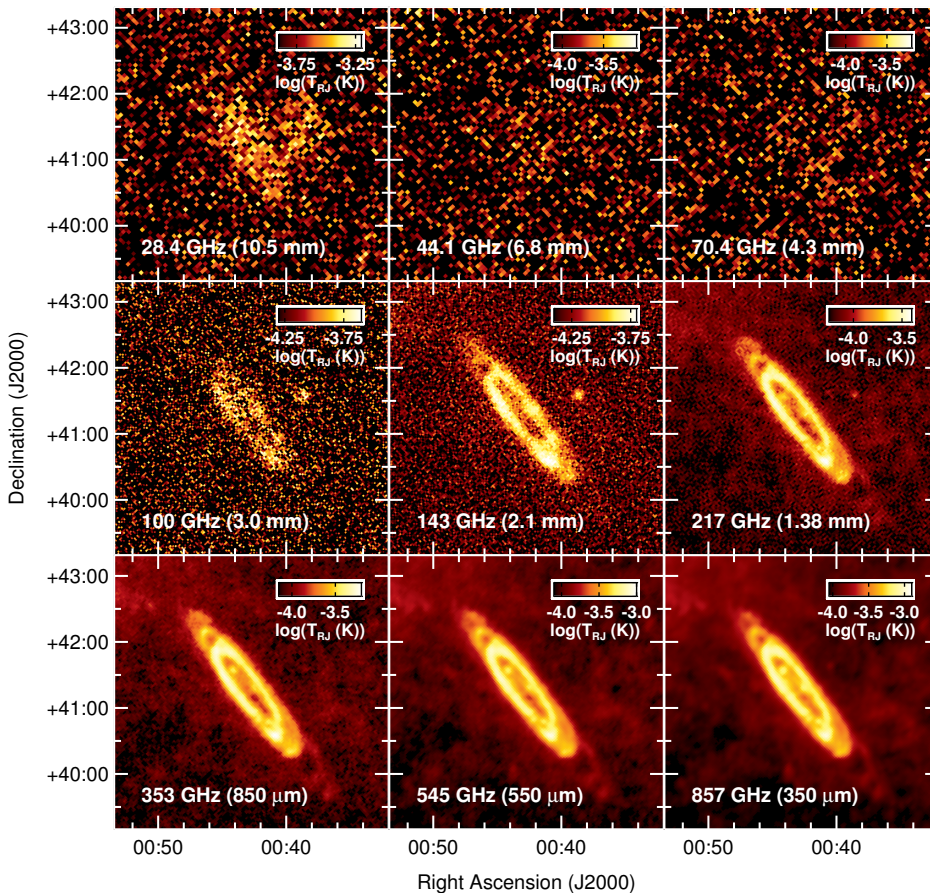
Mike Peel, AME Workshop, Noordwijk, June 2016



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

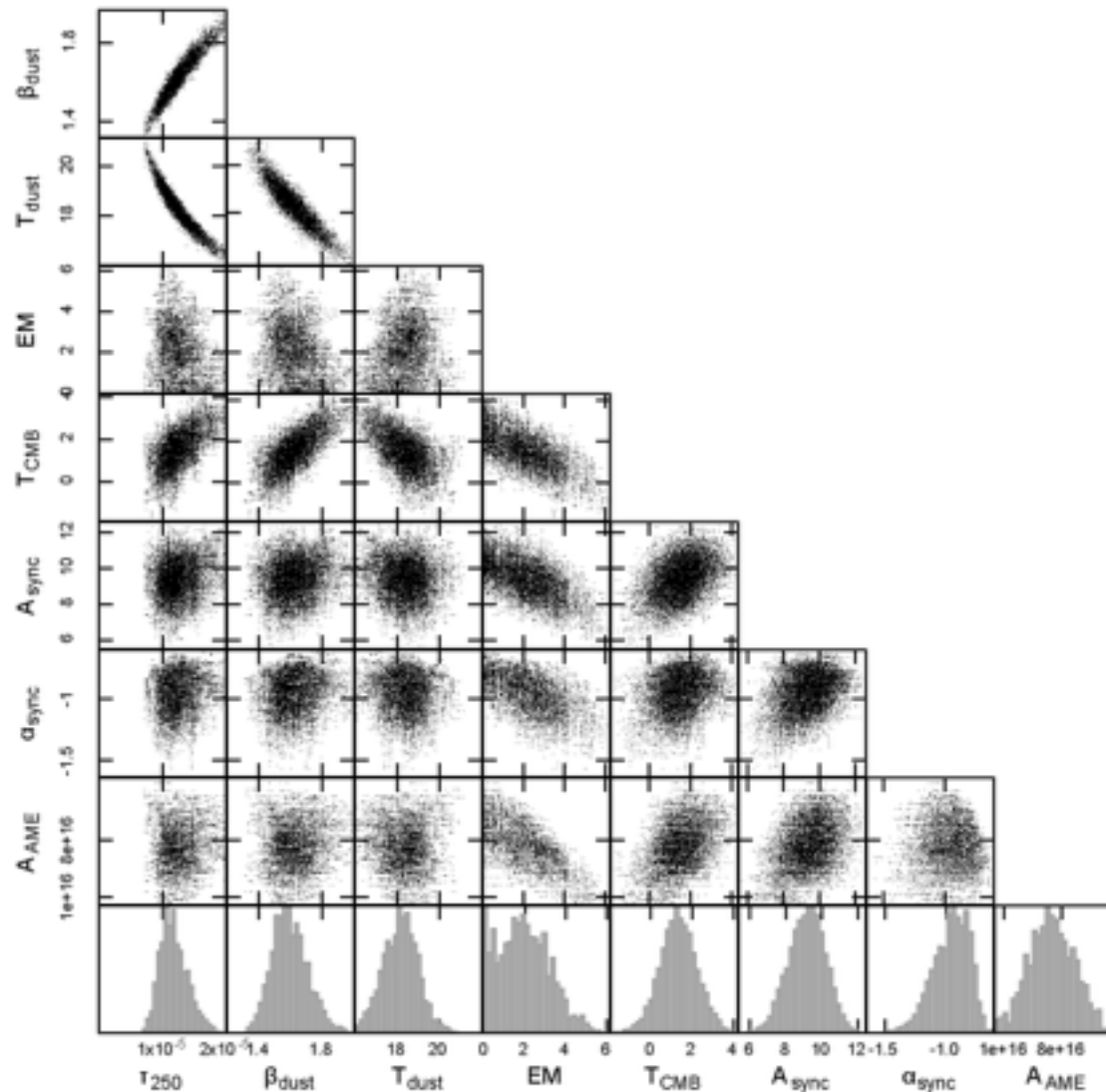
2.3 σ



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PIP XXV: Andromeda Galaxy



Commander component maps

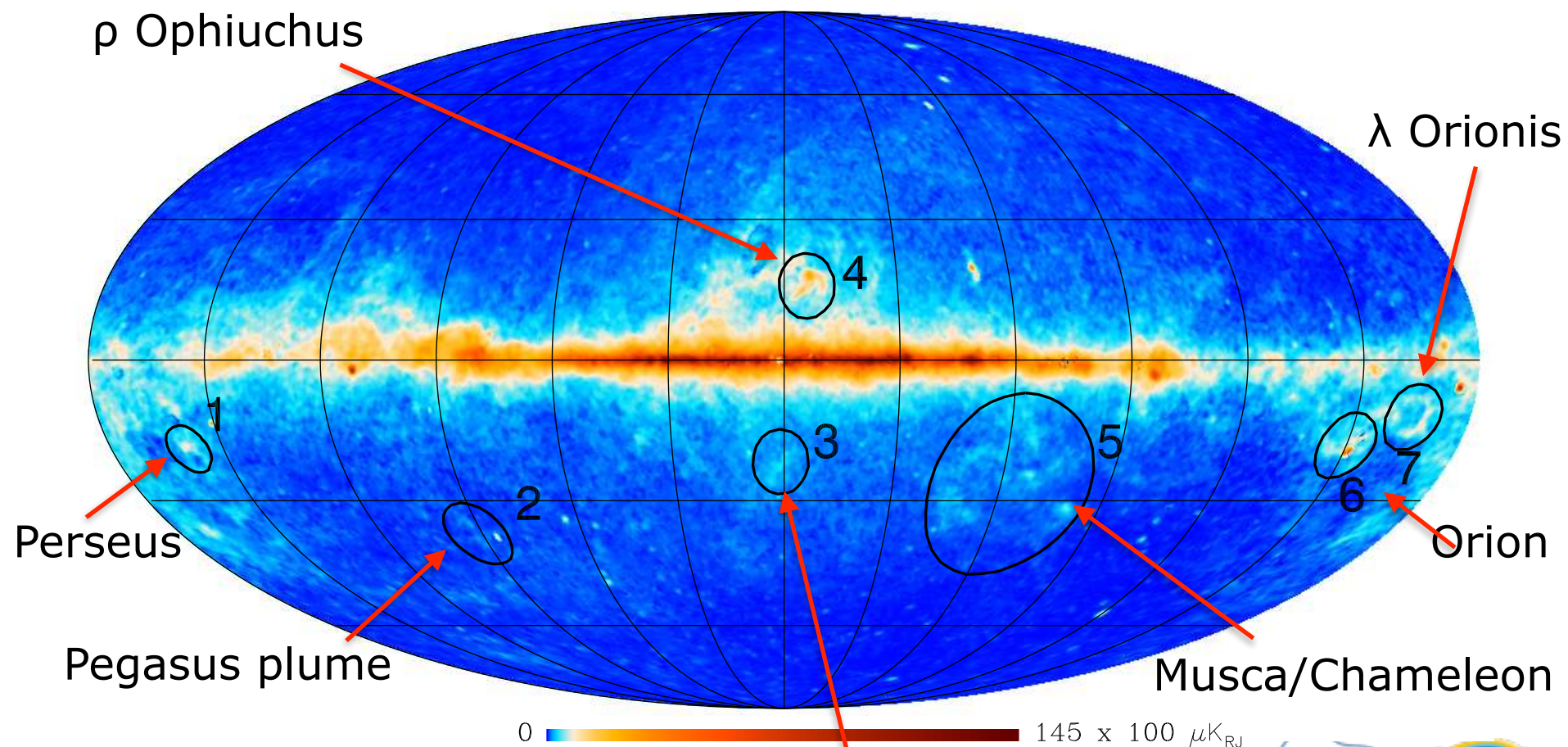


- Component separation mostly focuses on CMB maps, having e.g., a single low-frequency component. (see Planck Col. 2015. IX.)
- Commander: Bayesian technique, separate components using frequency information (see Eriksen et al. 2008)
- Thanks to many maps from Planck+WMAP+Haslam, we can separate:
 - Synchrotron (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).

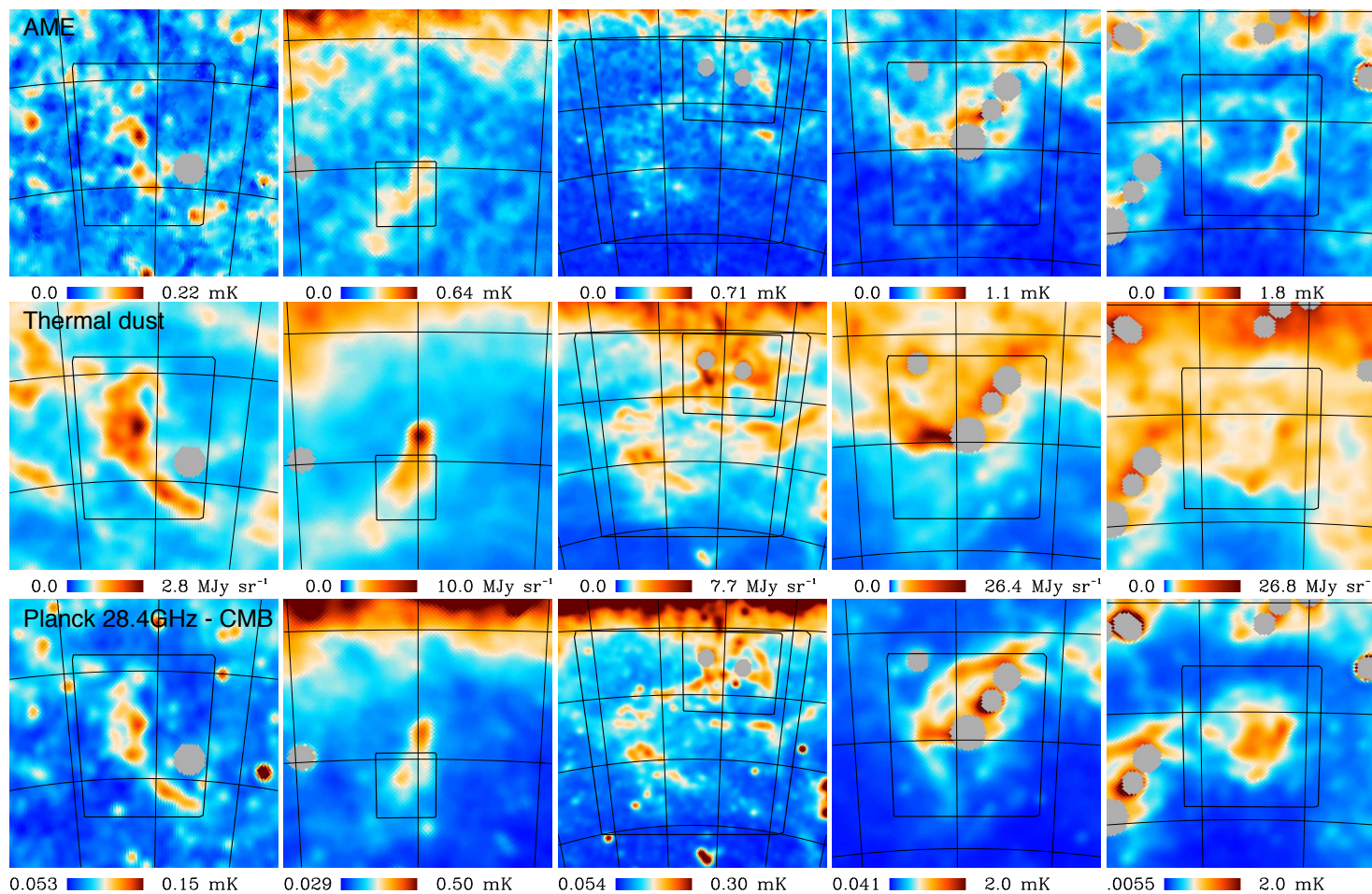
Anomalous Microwave Emission



Commander AME solution



New AME regions



Pegasus plume

Corona
Australis

Musca/
Chameleon

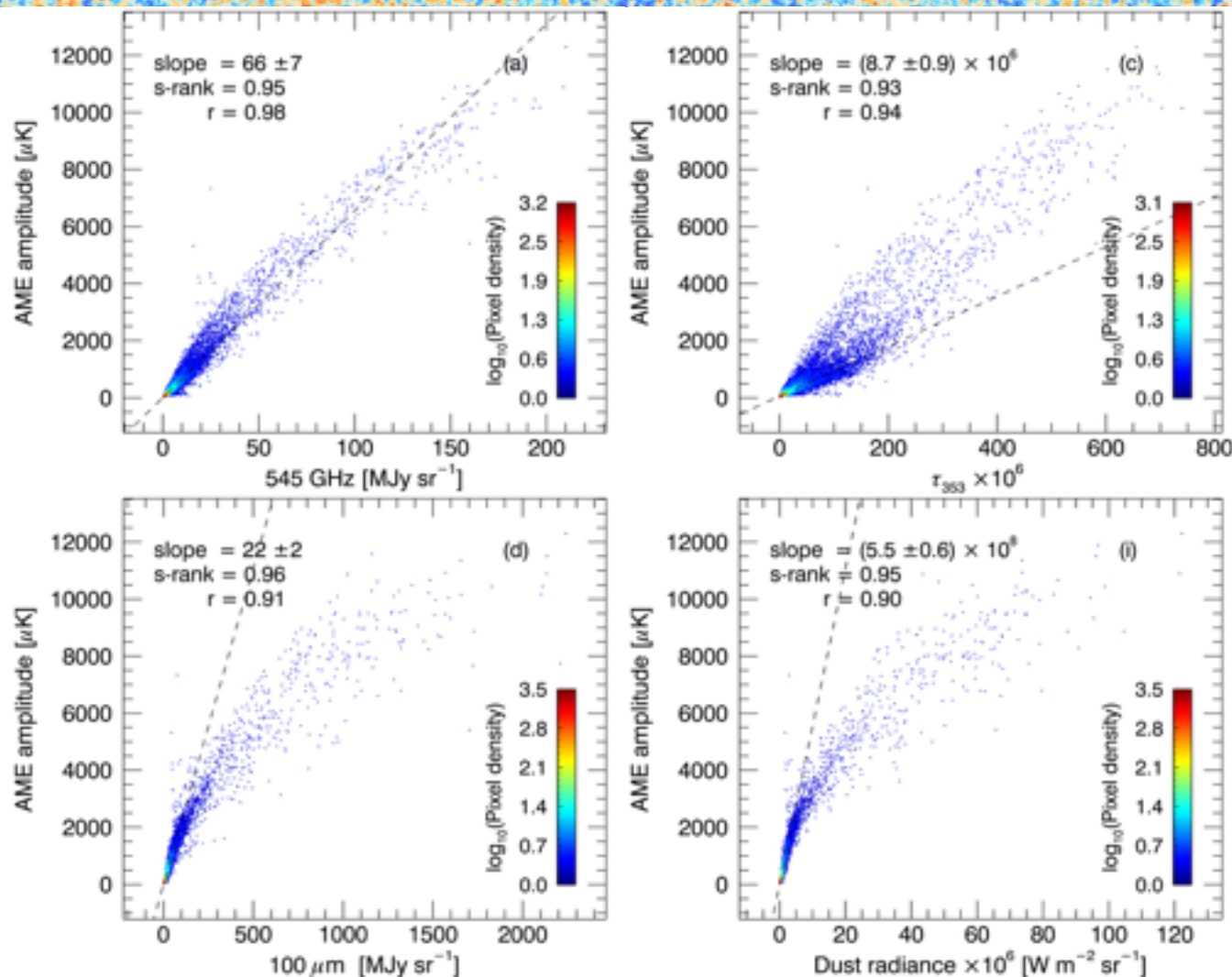
Orion

λ Orionis

AME correlations



planck



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 [$\mu\text{K (MJy sr}^{-1})^{-1}$]	AME/100 μm [$\mu\text{K (MJy sr}^{-1})^{-1}$]	AME/ τ_{353} [$\mu\text{K } 10^{-6}$]
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^\circ$	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



(b)

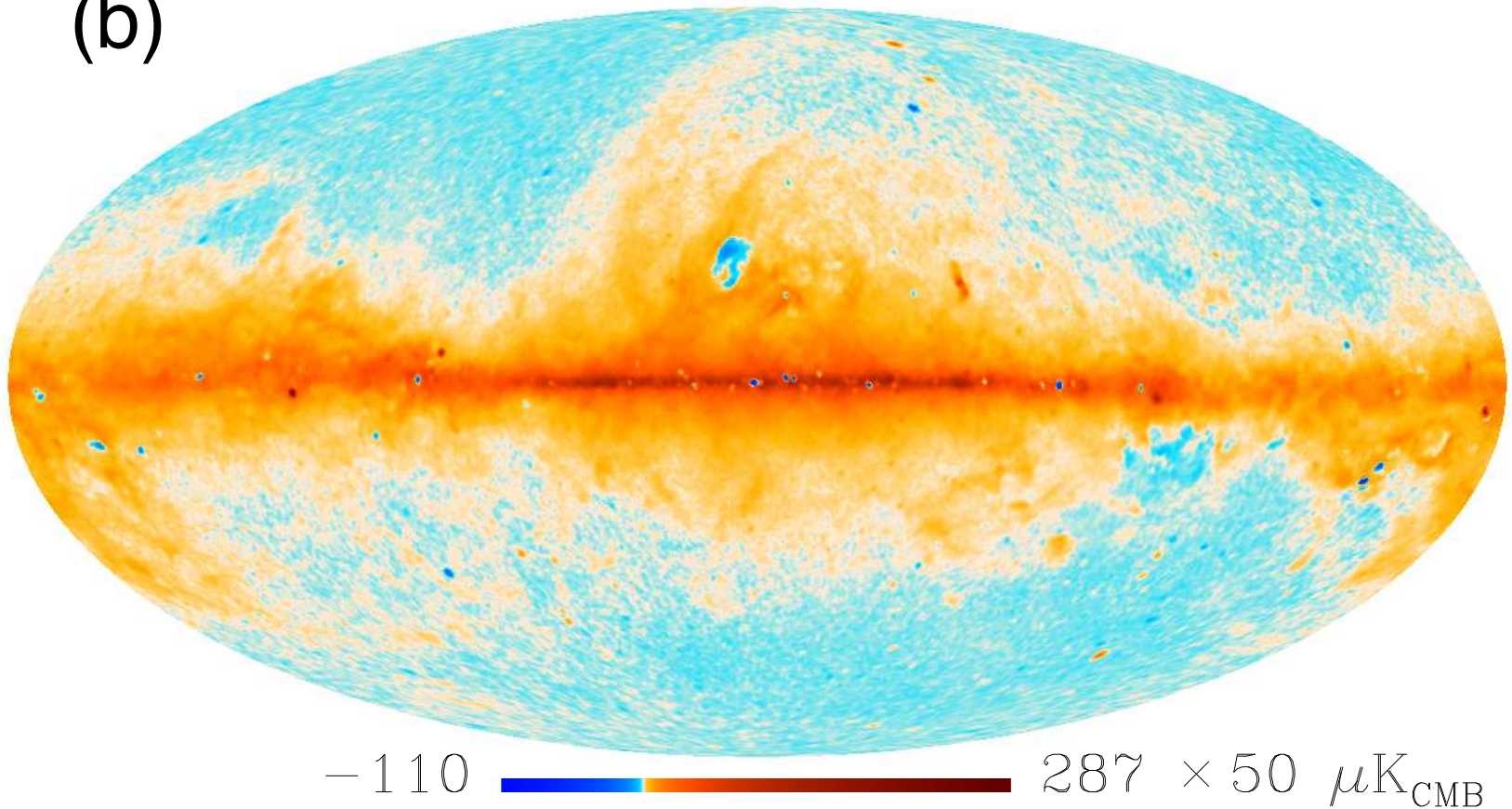


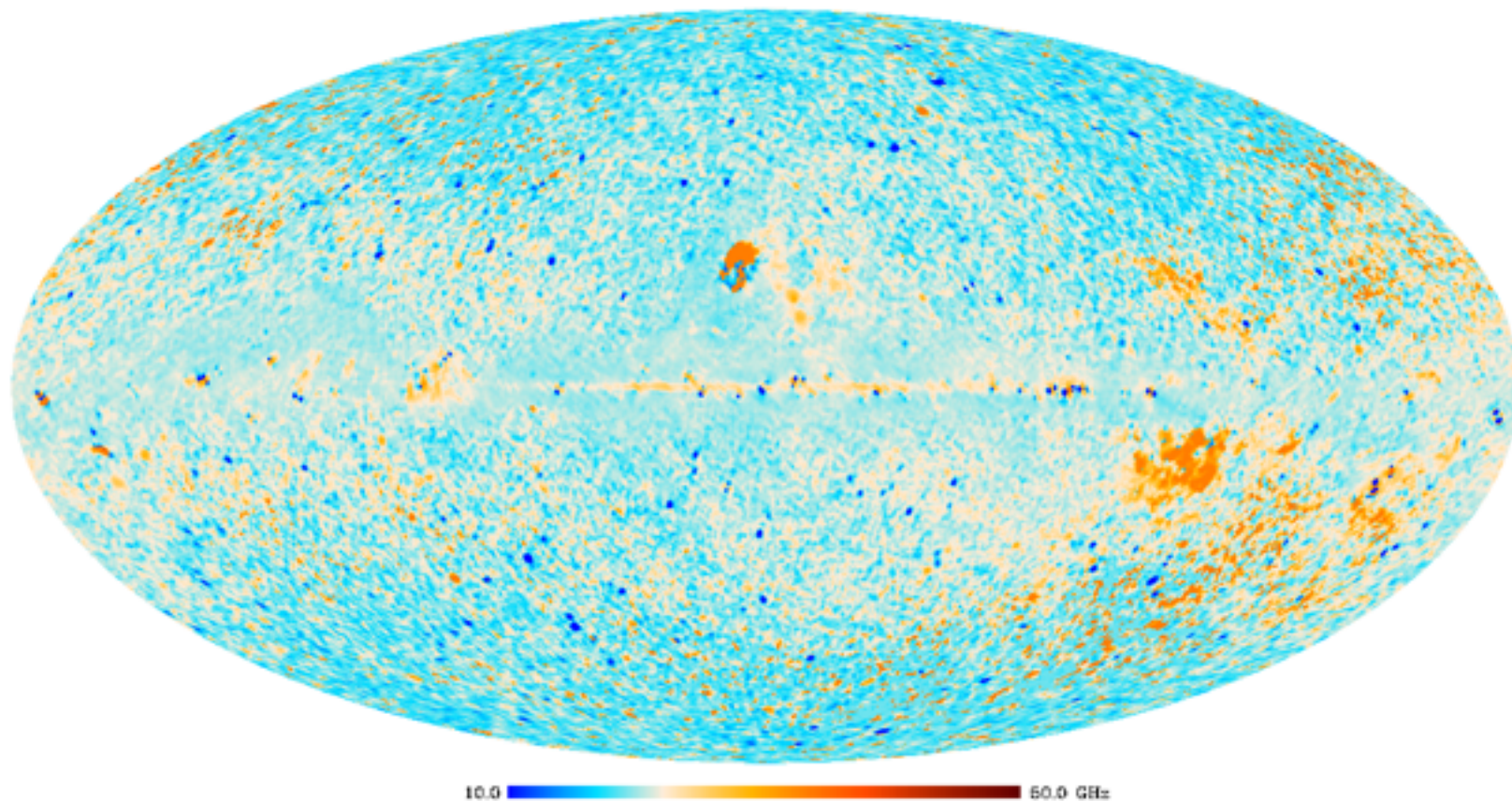
Fig 3b from Planck 2016 XXV. ILC with CMB, free-free and thermal dust nulled.

High-frequency peakers



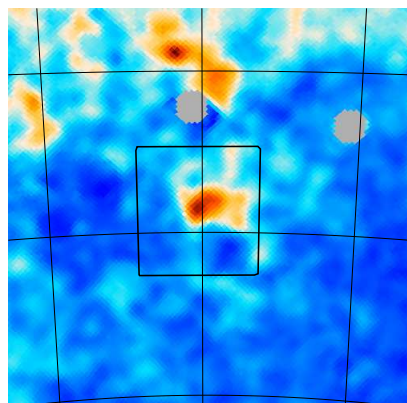
planck

Peak frequency from Commander (AME1+AME2)

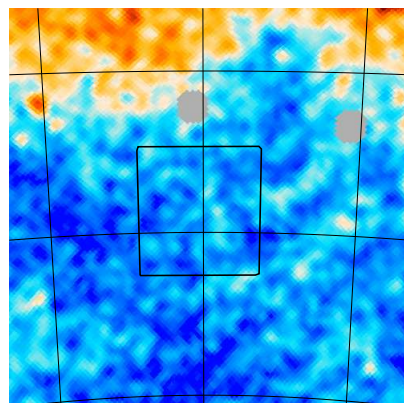


Combined peak frequency from the two AME components fitted by Commander

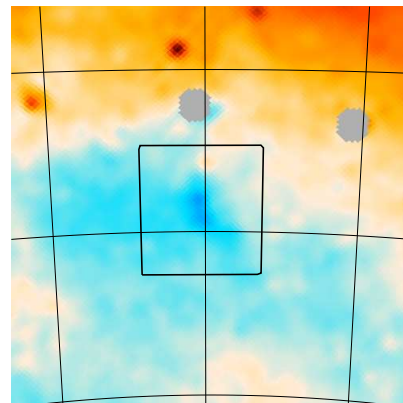
AME polarization



0.0 1.0 mK

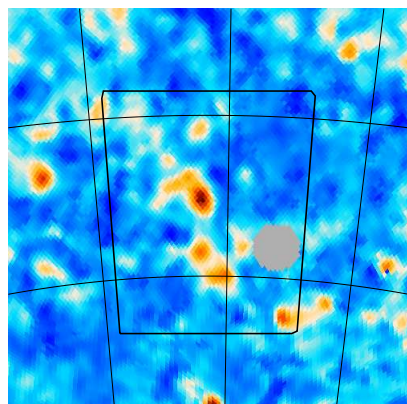


0.0 0.072 mK

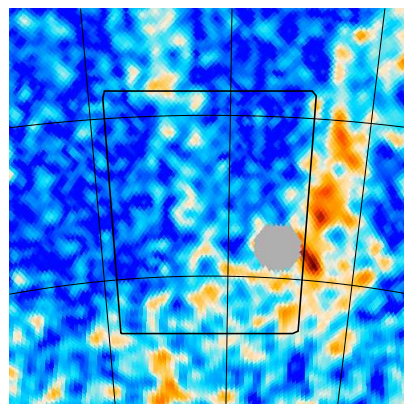


0.0 0.18 mK

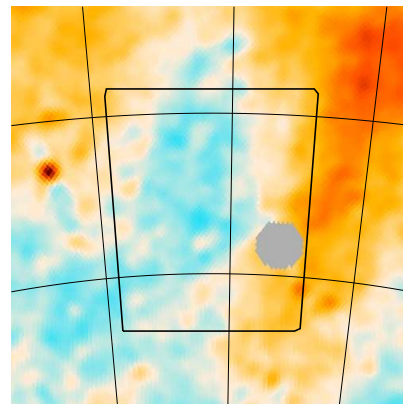
Perseus



0.0 0.22 mK

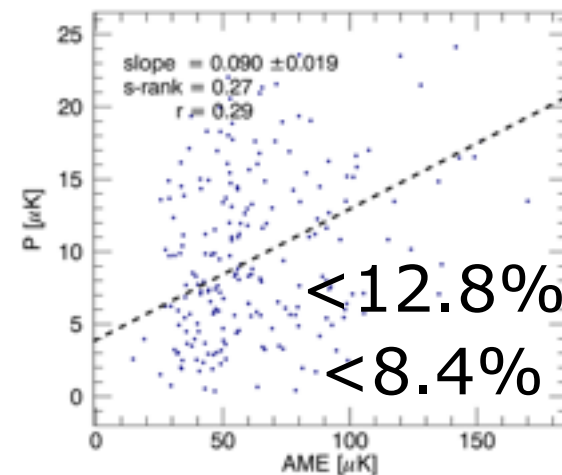
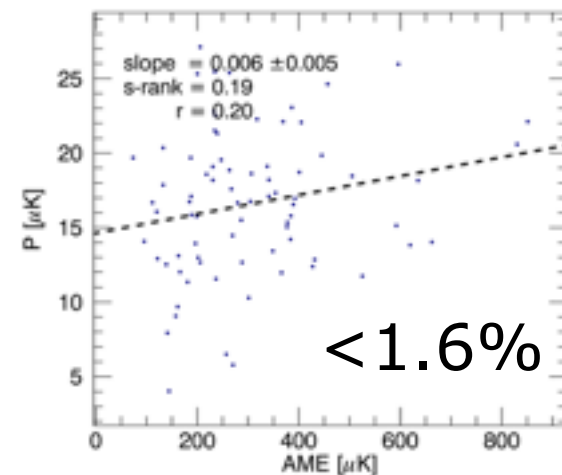


0.0 0.040 mK



0.0 0.10 mK

Plume



Spinning dust models predict low polarization fractions.



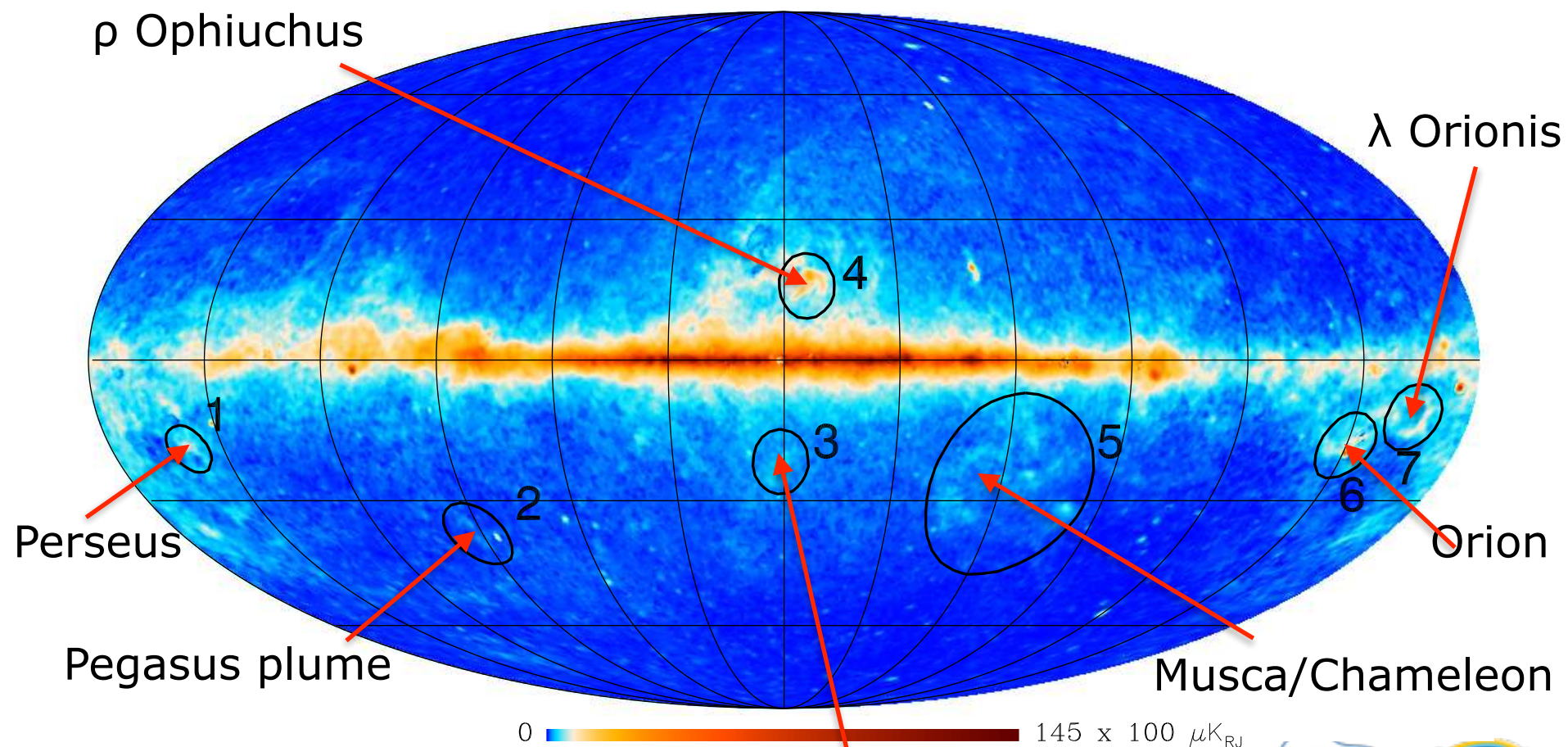
Mike Peel, AME Workshop, Noordwijk, June 2016



Anomalous Microwave Emission



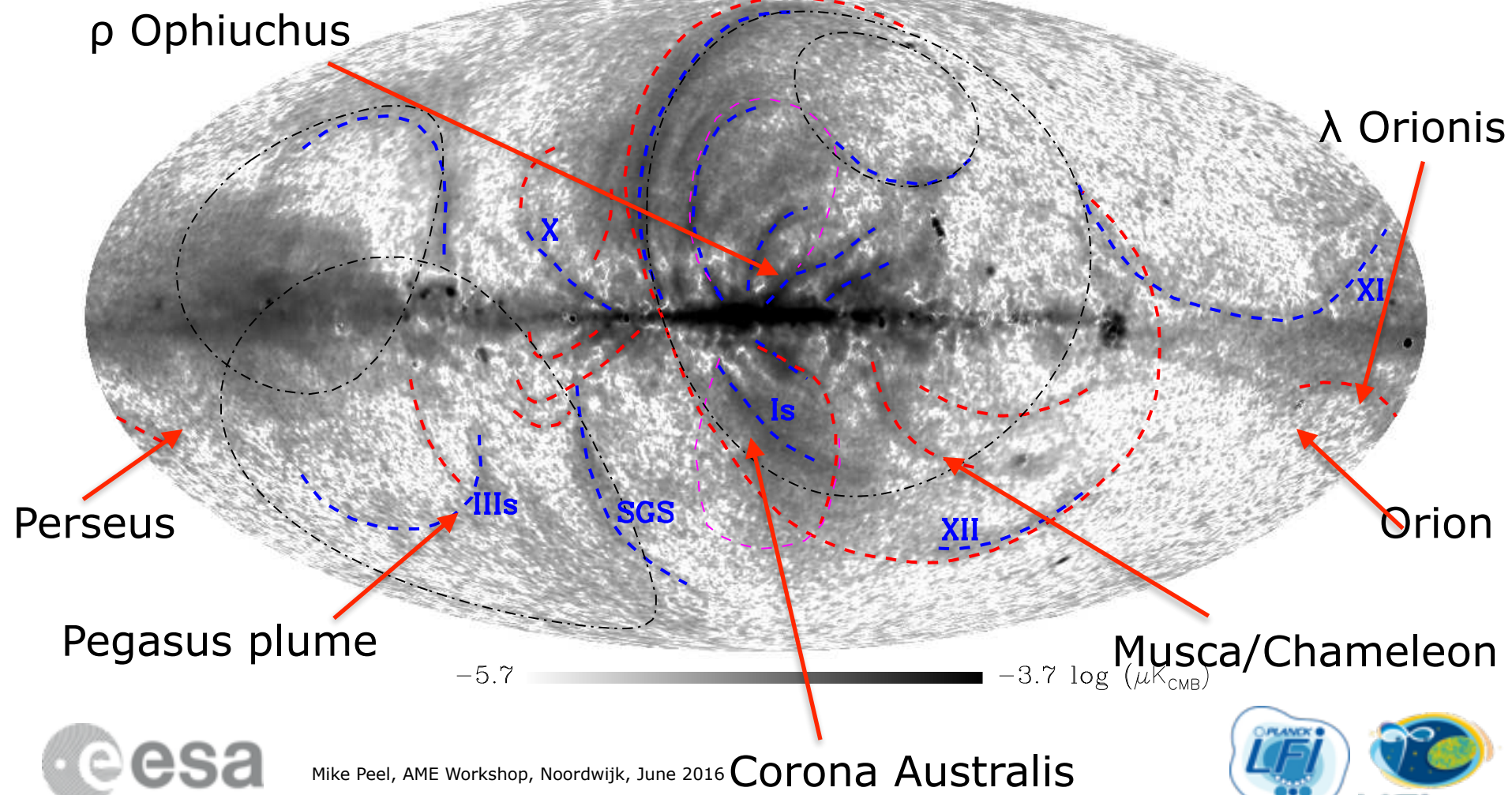
Commander AME solution



Anomalous Microwave Emission



Planck+WMAP polarisation



Comparison with WMAP



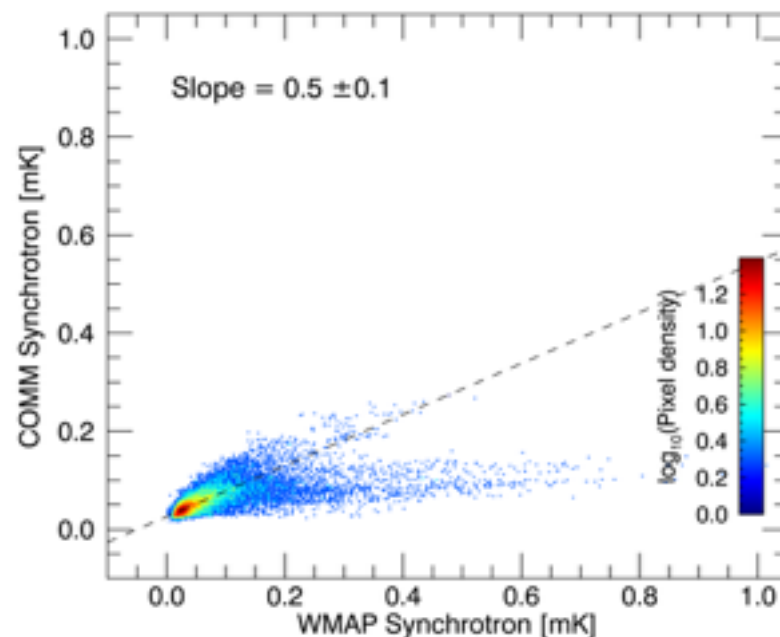
Run	Sync		Free-free		AME	
	<i>a</i>	<i>r</i>	<i>a</i>	<i>r</i>	<i>a</i>	<i>r</i>
MCMC-c base	0.50	0.62	0.68	0.77	...	...
MCMC-e sdcnm	0.52	0.92	0.77	0.87	4.91	0.75
MCMC-f fs	0.52	0.62	0.80	0.77	3.18	0.67
MCMC-g fss	0.55	0.62	0.77	0.78	3.14	0.70
MEM	0.34	0.84	0.76	0.79	2.18	0.86

$|b| > 20^\circ$

$a > 1$ = commander > WMAP

Trust values if $r \geq 0.9$

AME systematically higher
Free-free about the same
Synchrotron lower



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

Large Magellanic Cloud



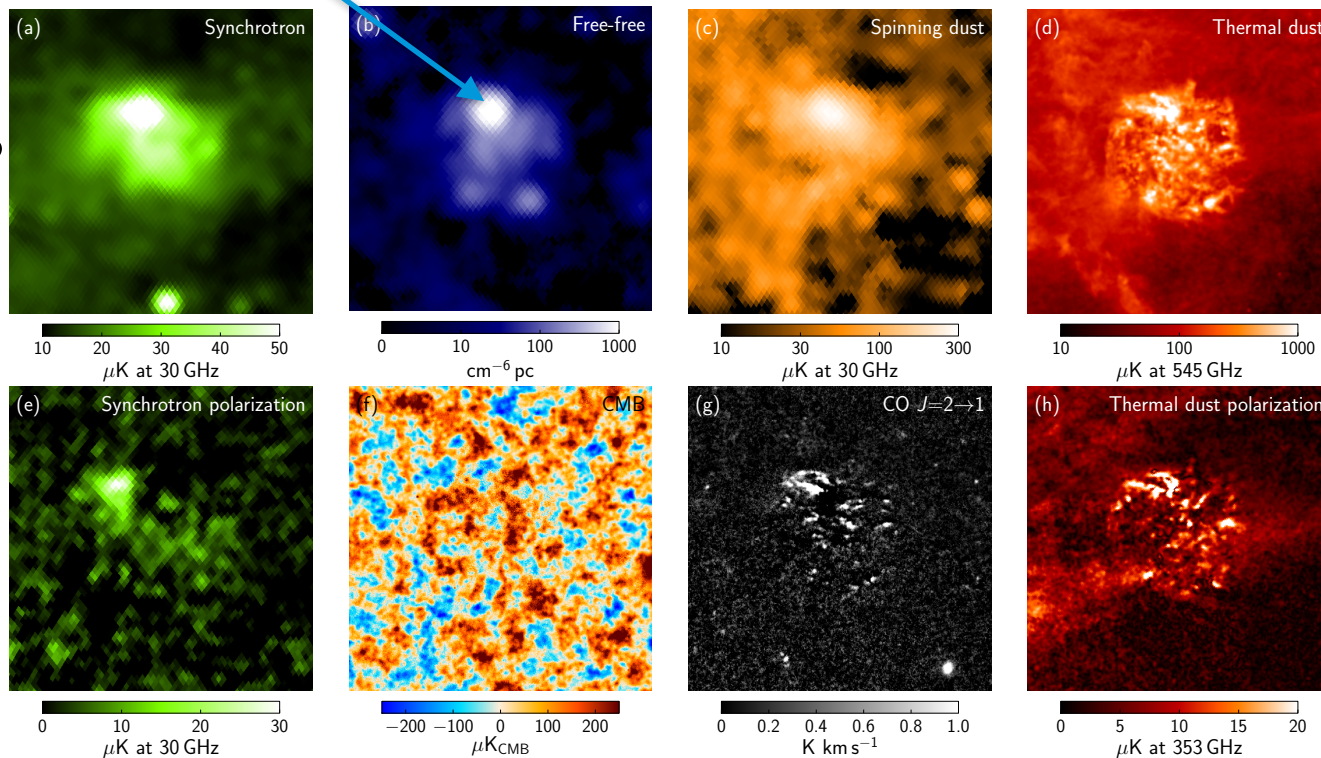
30 Dor

Dominates
SED

AME emissivities comparable
to our Galaxy (except 100 μ m)

Could be
too steep?

Up to
30% pol.



Clean
CMB map

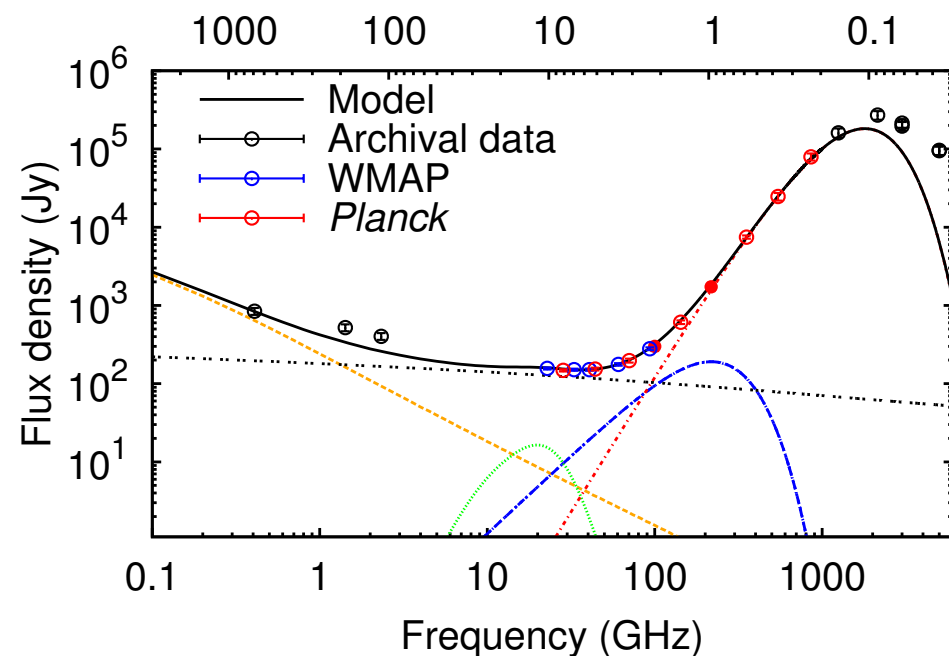
Good agreement
with ground-
based surveys

Large & Small Magellanic Clouds



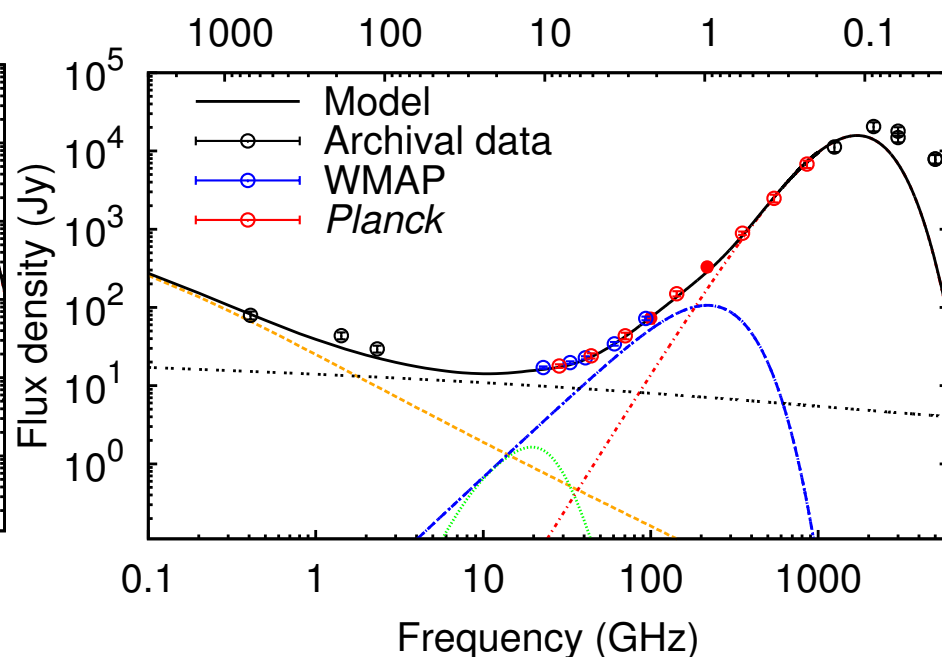
LMC

Wavelength (mm)



SMC

Wavelength (mm)



AME $< \sim 0.2 \text{ Jy}$

c.f. 3-5 Jy from Hensley

Conclusions

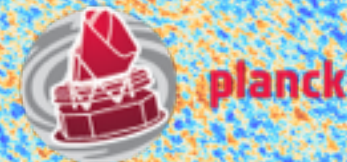


1. Commander has done a relatively clean separation of Planck & WMAP data into synchrotron, free-free, AME & thermal dust emission (+CO, HCN)
2. AME emission seems best correlated with thermal dust at 545GHz.
3. New diffuse AME regions identified, λ Orionis particularly interesting.
4. Upper limit on 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.



Planck is a project of the European Space Agency, 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.



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DTU Space
National Space Institute



National Research Council of Italy



Deutsches Zentrum für Luft- und Raumfahrt e.V.





Thank you