WMAP 3yr Data

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CITA–ICAT

Ecole Chalonge, 26 Oct 2006

WMAP3 Science Team

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MAP990387

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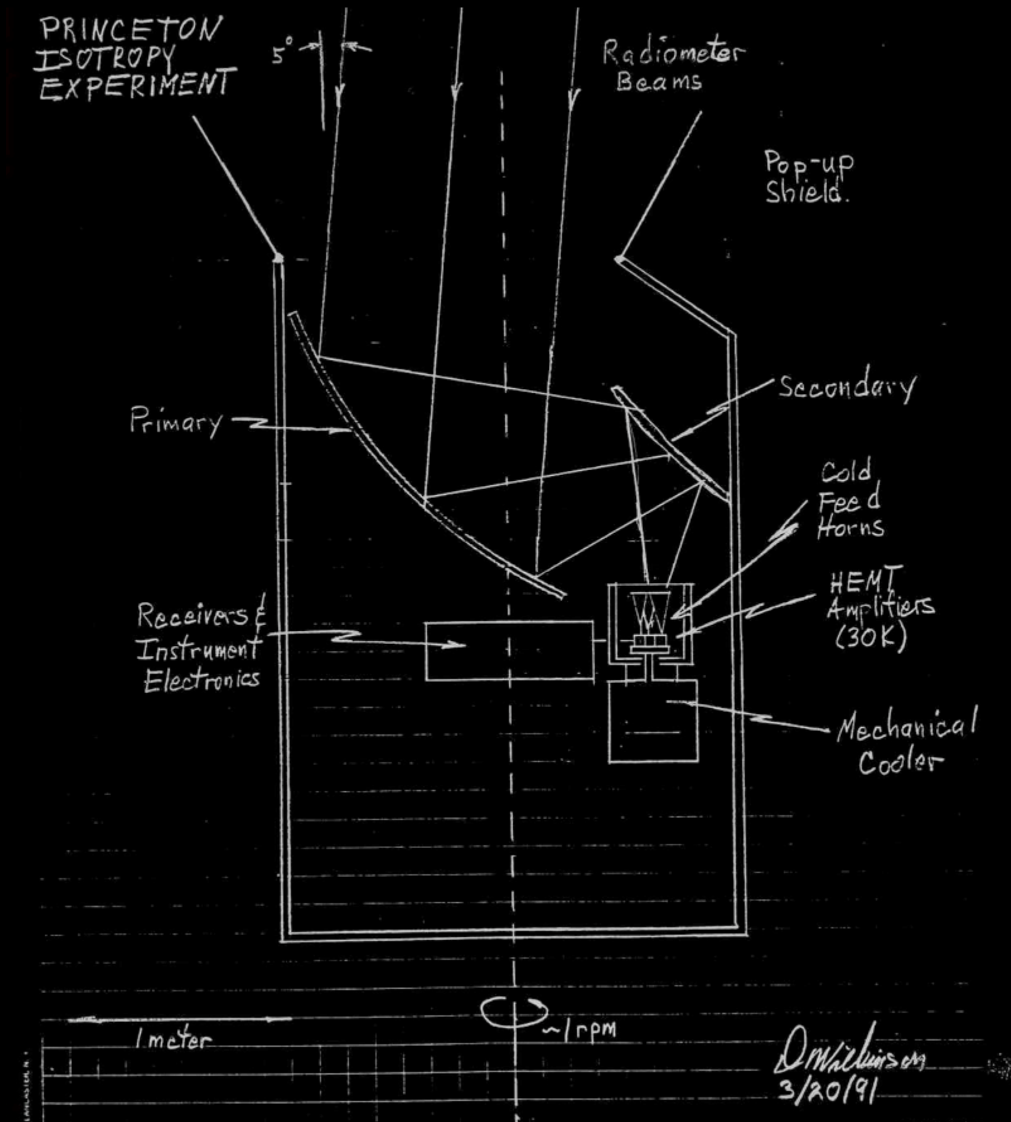
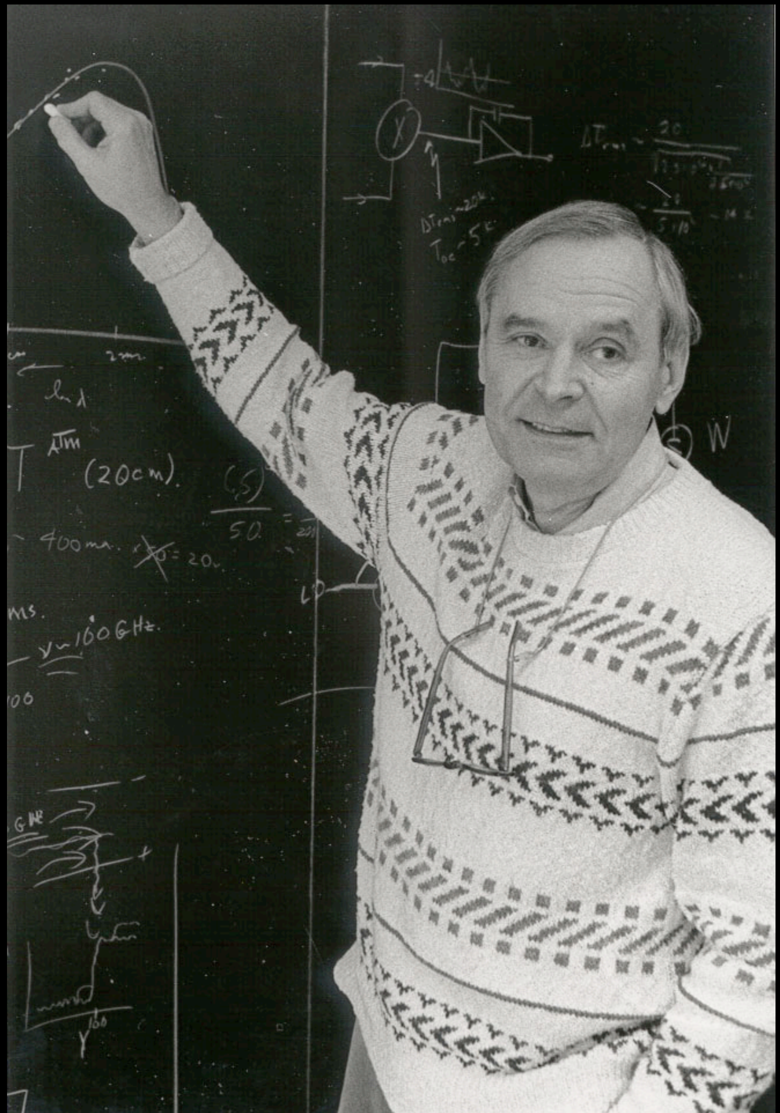
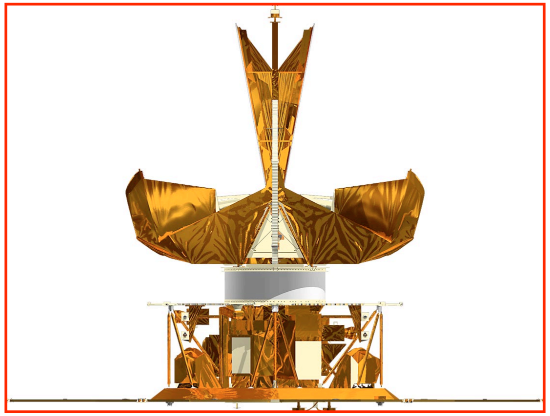
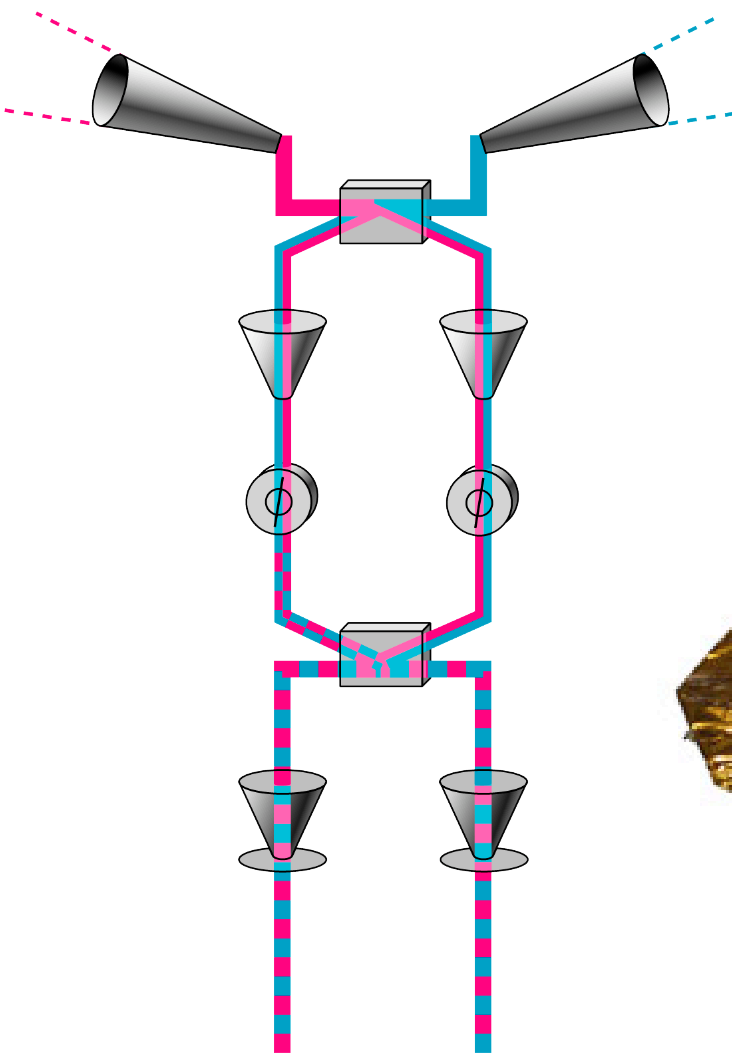
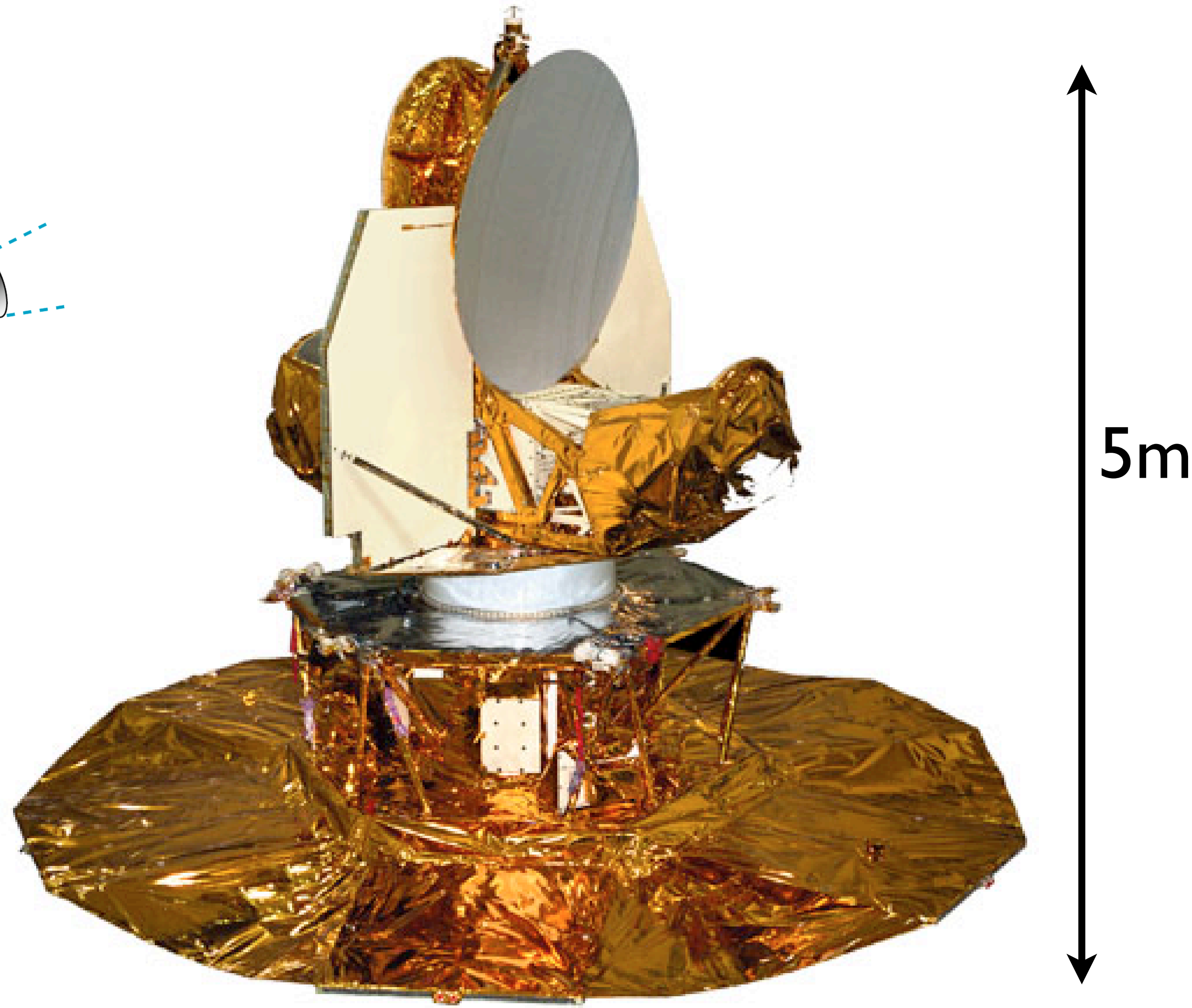


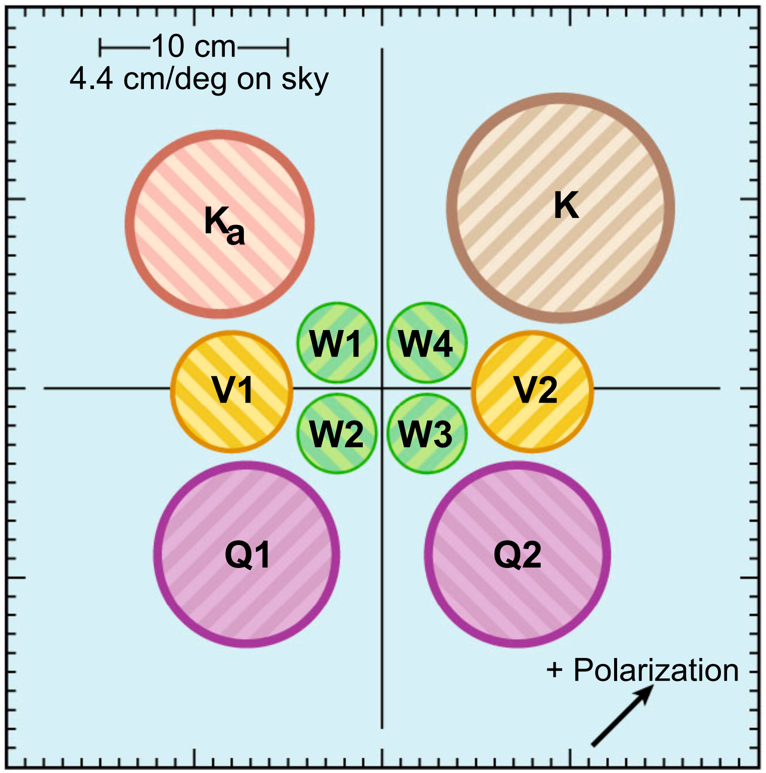




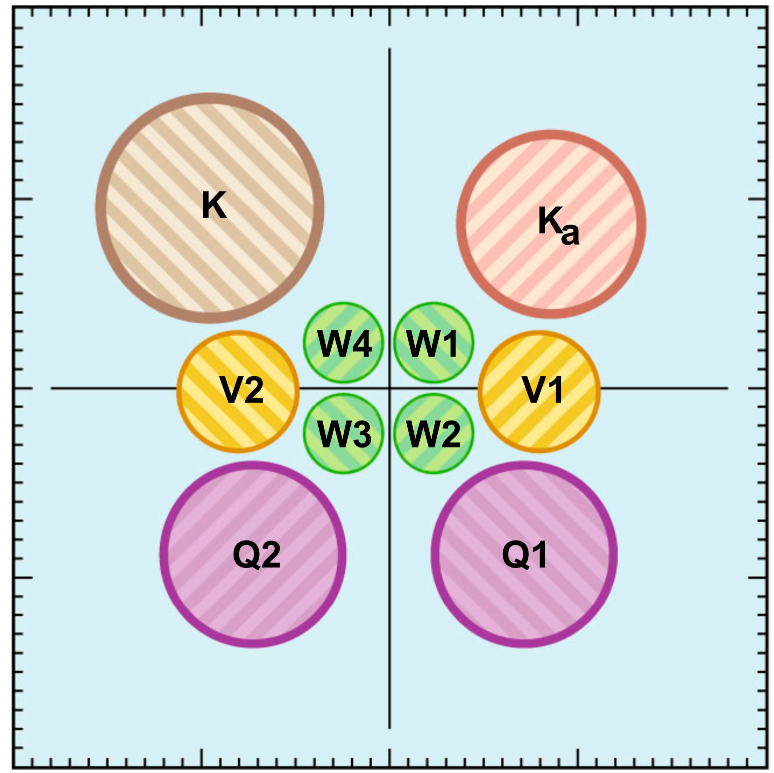



5m

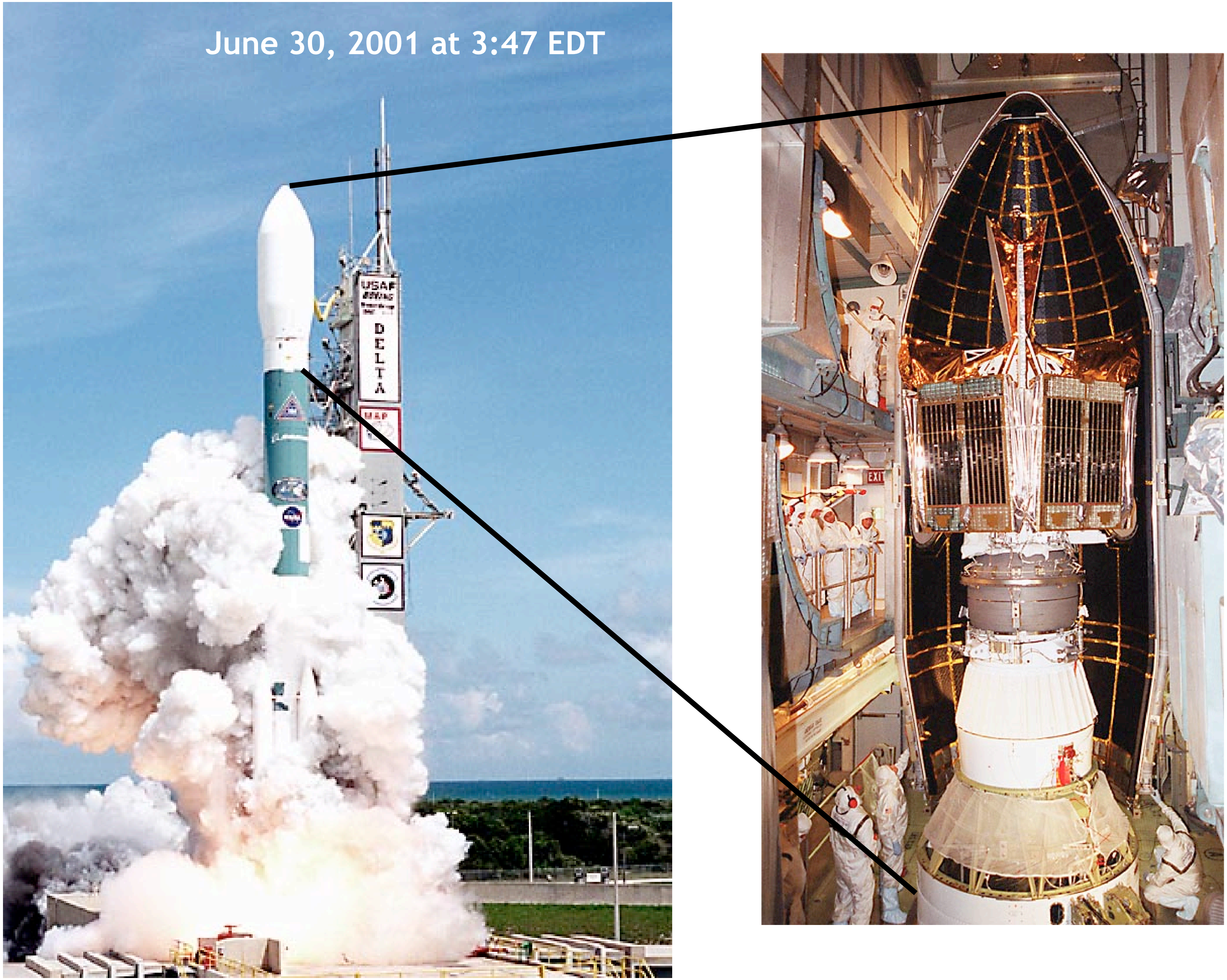
Focal Plane

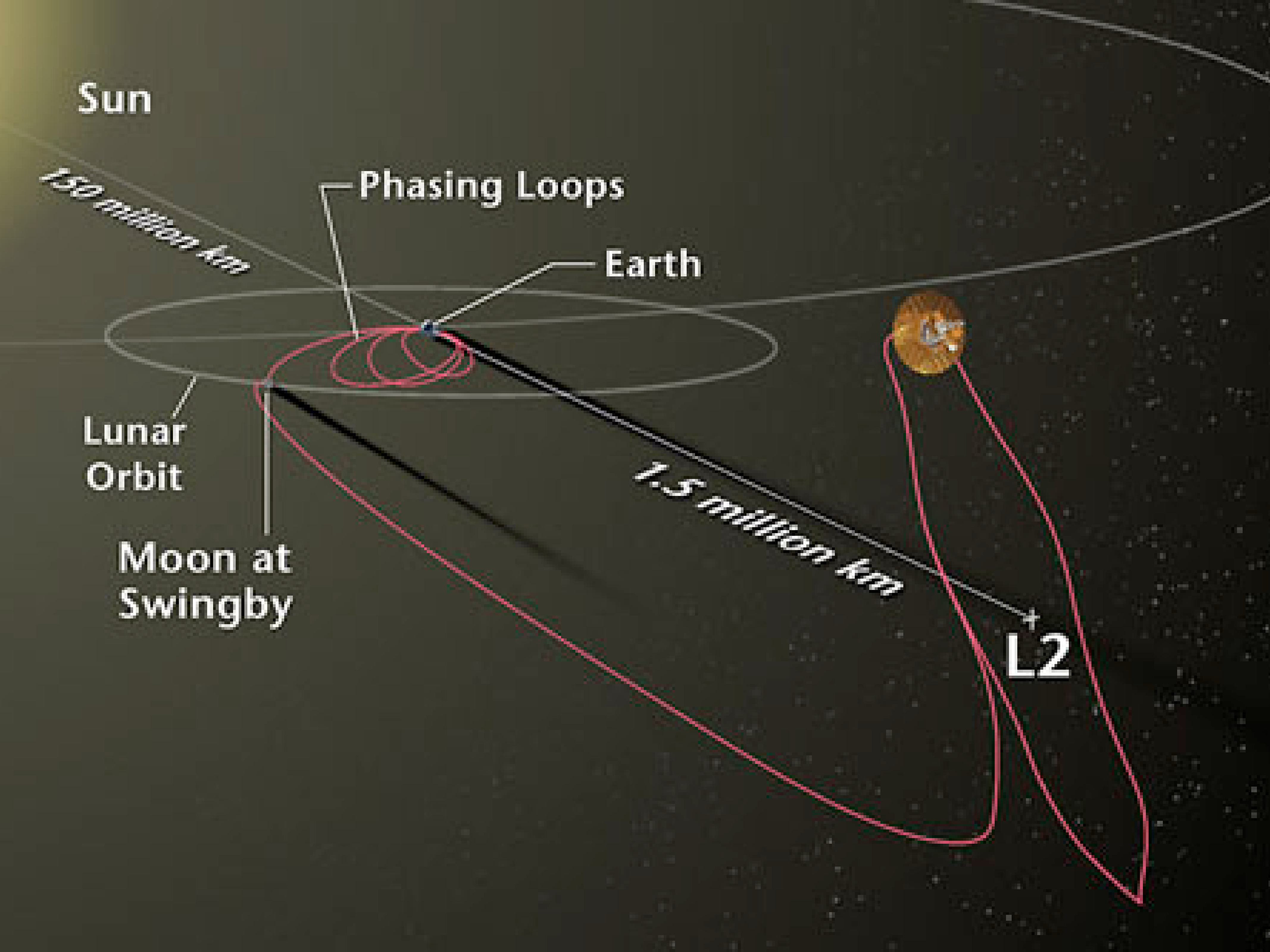


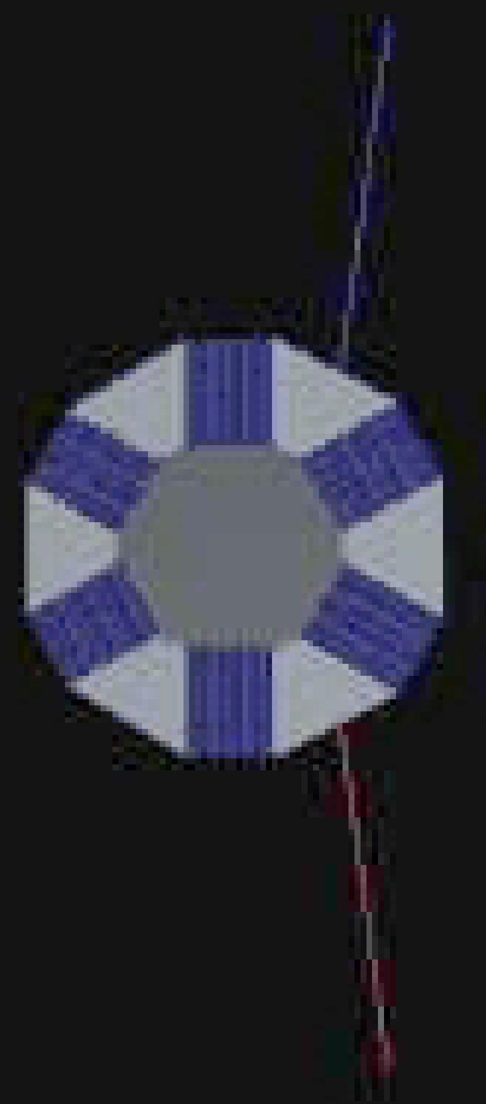
Side A

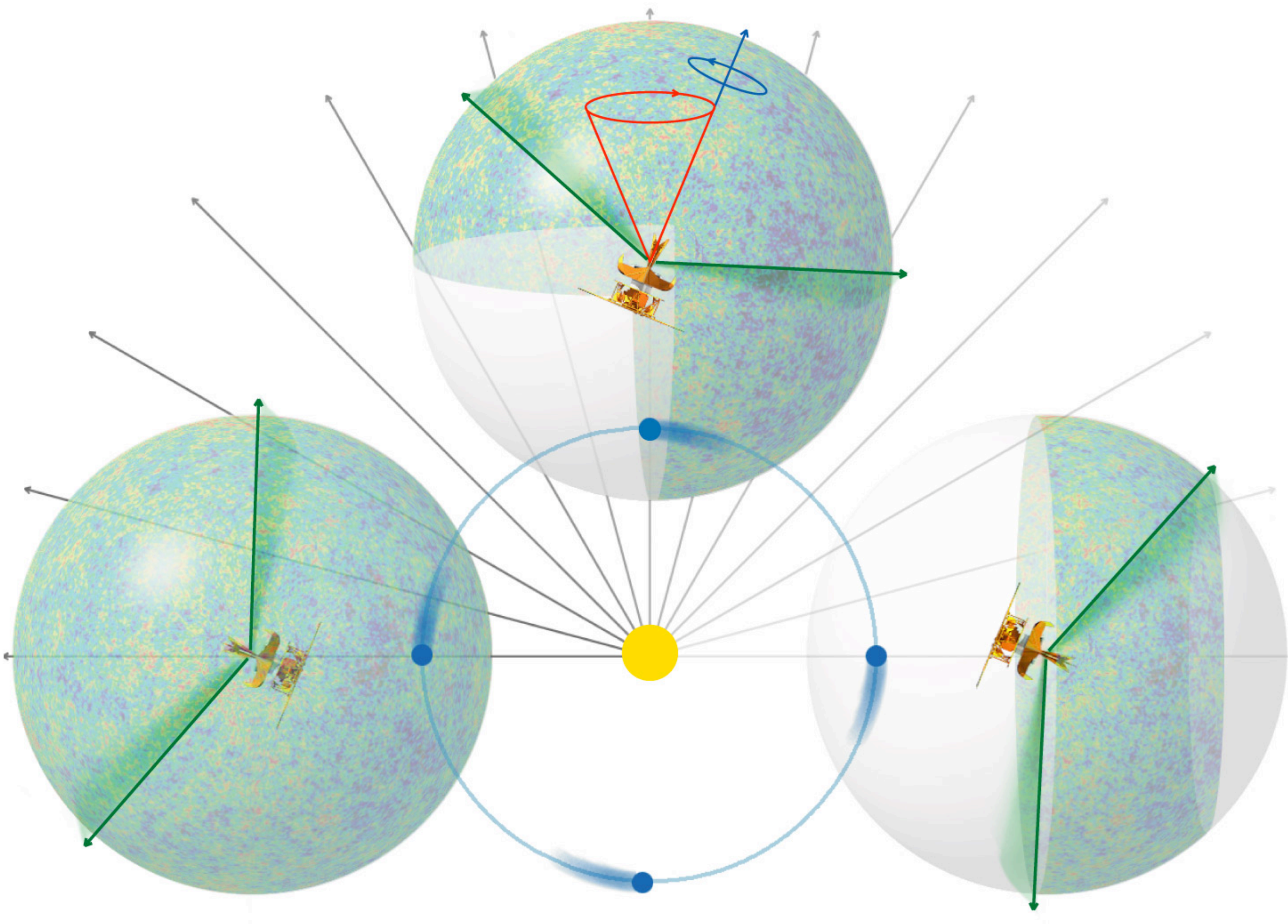


Side B


June 30, 2001 at 3:47 EDT
USAF
DELTA
MAP
EXIT


Sun
150 million km
Phasing Loops
Earth
Lunar
Orbit
Moon at
Swingby
1.5 million km
L2

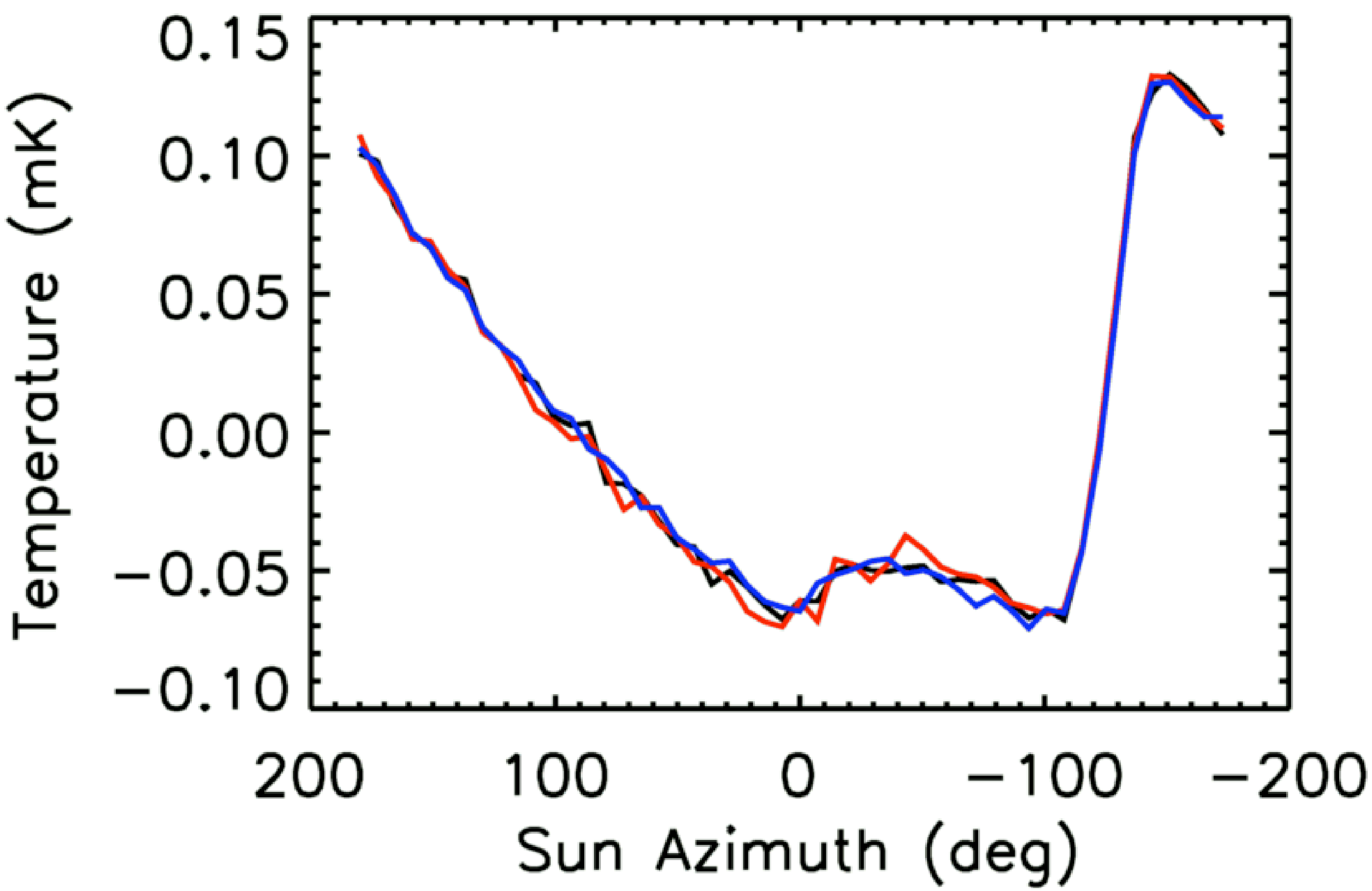




The 3-yr release

- 3-years of observations (will have 5 in October)
- Satellite still working great - no problems!
- New map-making pipeline:
  - solve for maximum likelihood solution instead of prewhitening
  - updated physical gain model
  - account for bandpass mismatch leaking into polarization
- Updated beam modeling with better determination of solid angle (~1%)
- Better understanding of large-scale noise structure
- And last but not least... much improved polarization S/N!

Satellite stability



Temp of B-side primary mirror for years 1,2,3

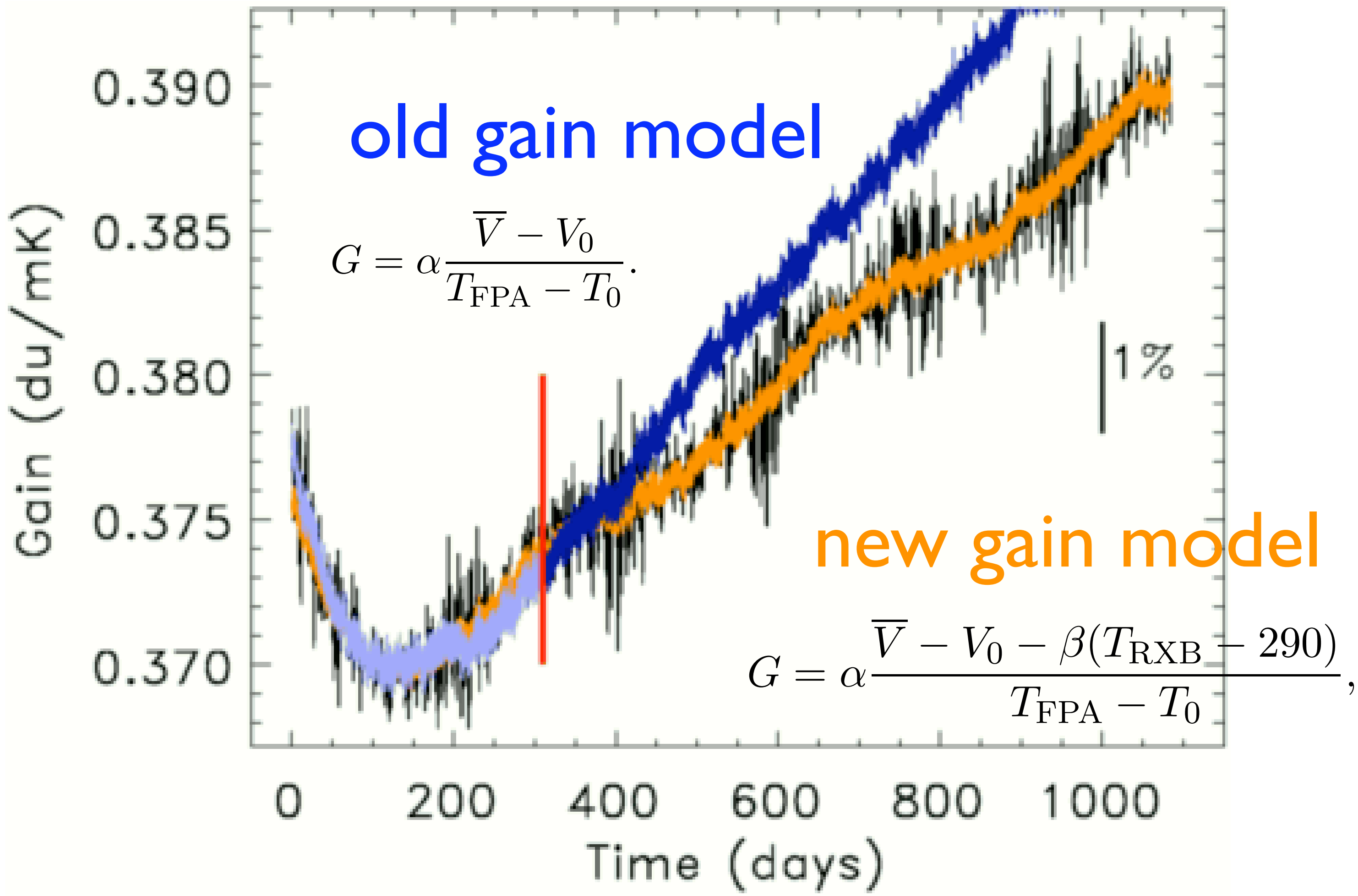
Table 2. Data Flagging Summary

Category	K-band	Ka-band	Q-band	V-band	W-band
Lost or rejected data					
Lost[a] (%)	0.43	0.43	0.43	0.43	0.43
Thermal disturbance[b] (%)	0.51	0.51	0.51	0.51	0.51
Gain/baseline step (%)	0.02	0.04	0.05	0.00	0.06
Total lost or rejected (%)	0.96	0.98	0.99	0.94	1.00
Data not used in maps					
Planet in beam (%)	0.11	0.11	0.11	0.11	0.11

[a]Primarily due to one solar storm induced safehold.

[b]Primarily due to station-keeping maneuvers at L_2.

Updated gain model



1yr/3yr T map comparison

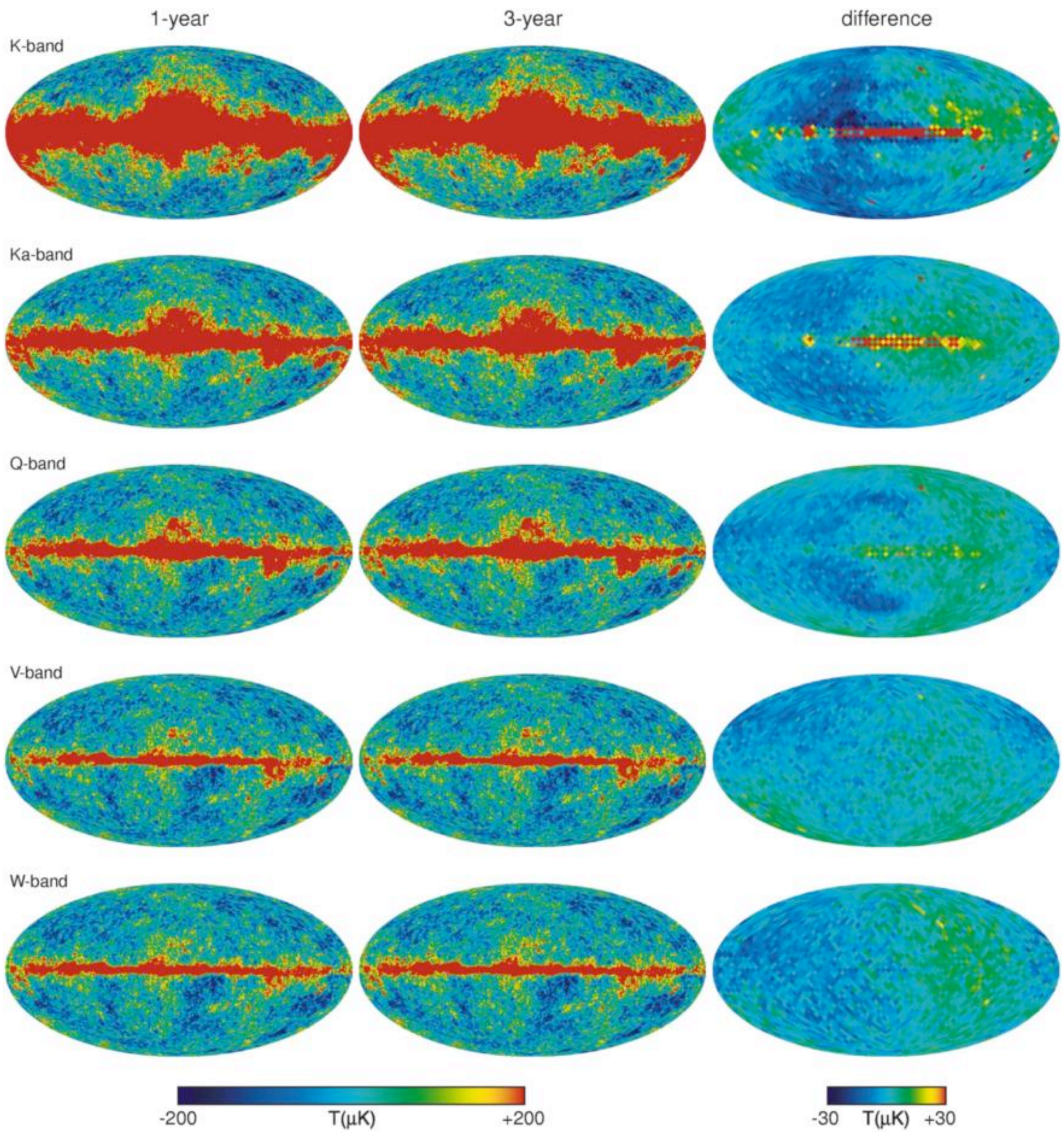


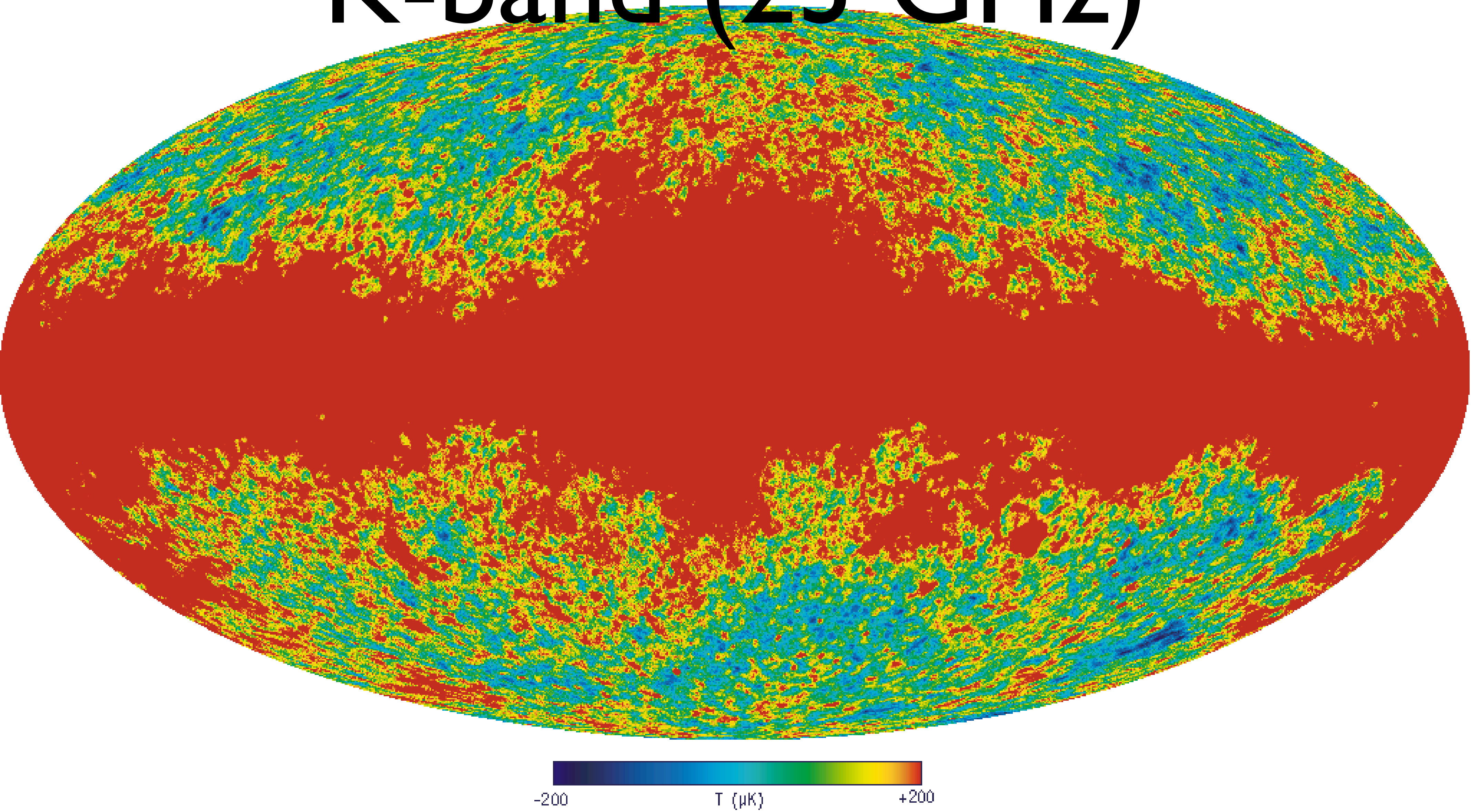
Table 3. Change in low-l Power

Band	$l = 1^{a}$ (μK)	$l = 2^{b}$ (μK^2)	$l = 3^{b}$ (μK^2)
K	10.1	38.8	9.1
Ka	7.3	2.7	3.4
Q	6.1	7.1	12.3
V	5.1	7.1	2.2
W	7.0	5.8	1.5

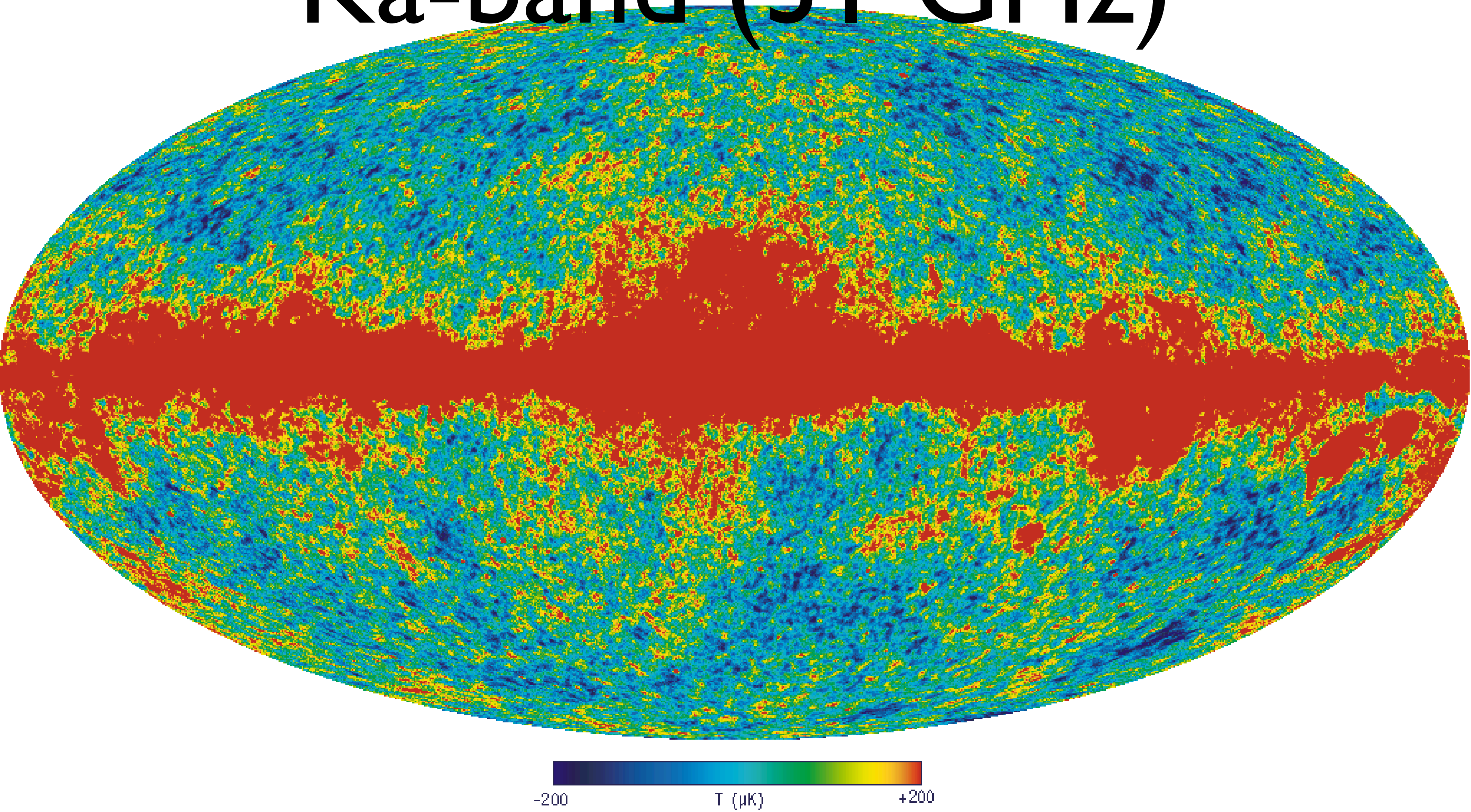
[a] $l = 1$ - Amplitude in the difference map, in μK.

[b] $l > 1$ - Power in the difference map, $l(l+1)\,C_l/2\pi$, in μK^2.

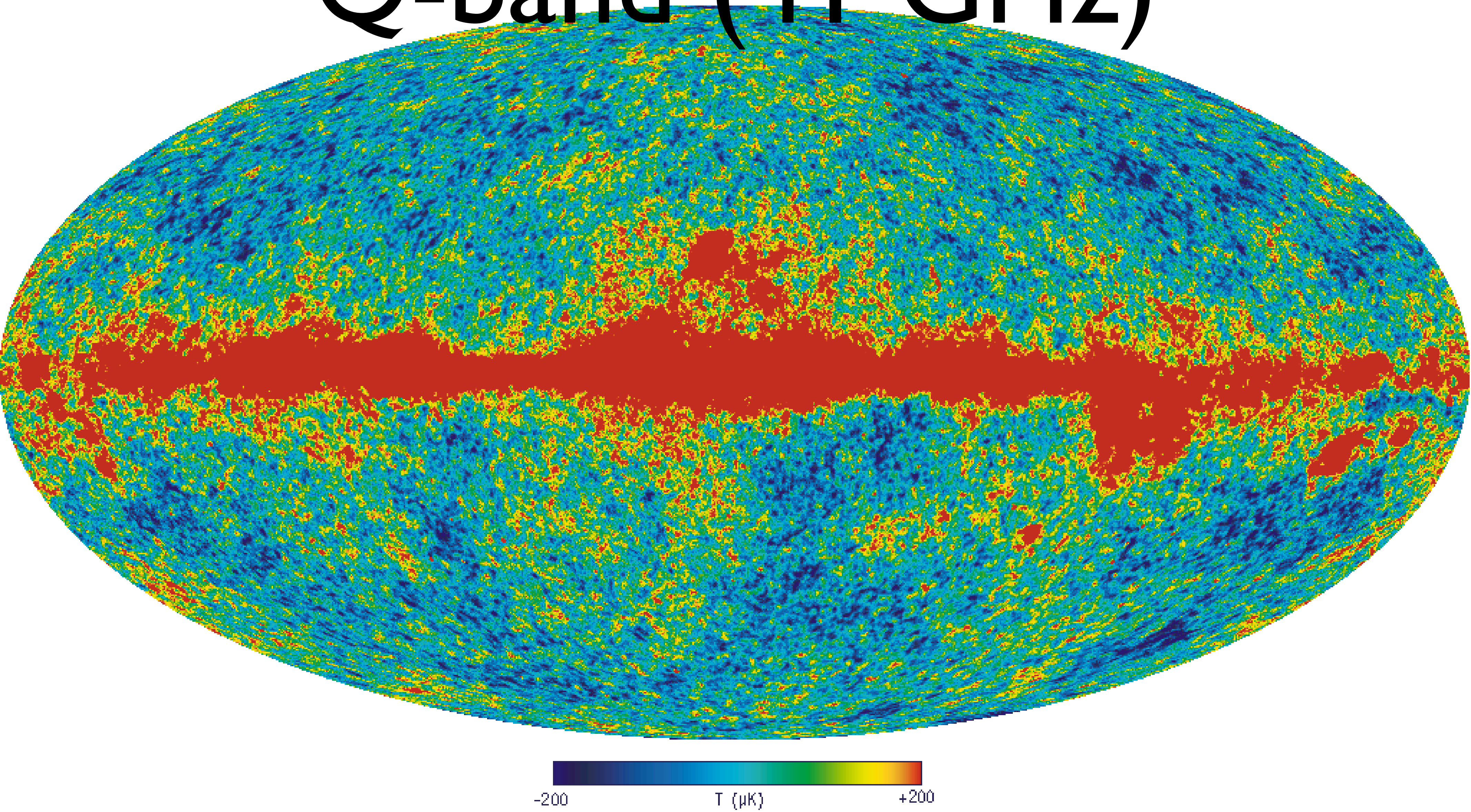
K-band (23 GHz)



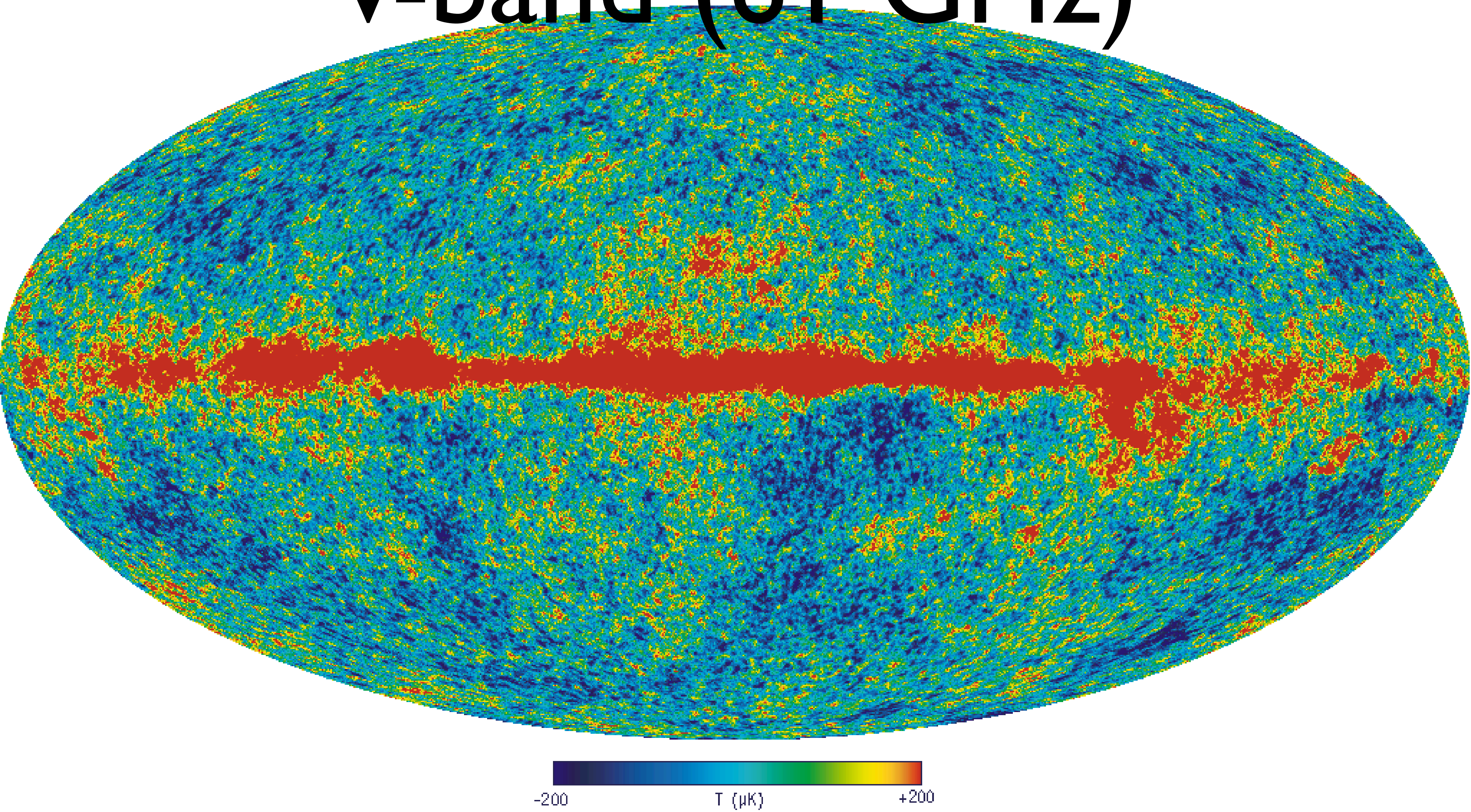
Ka-band (31 GHz)



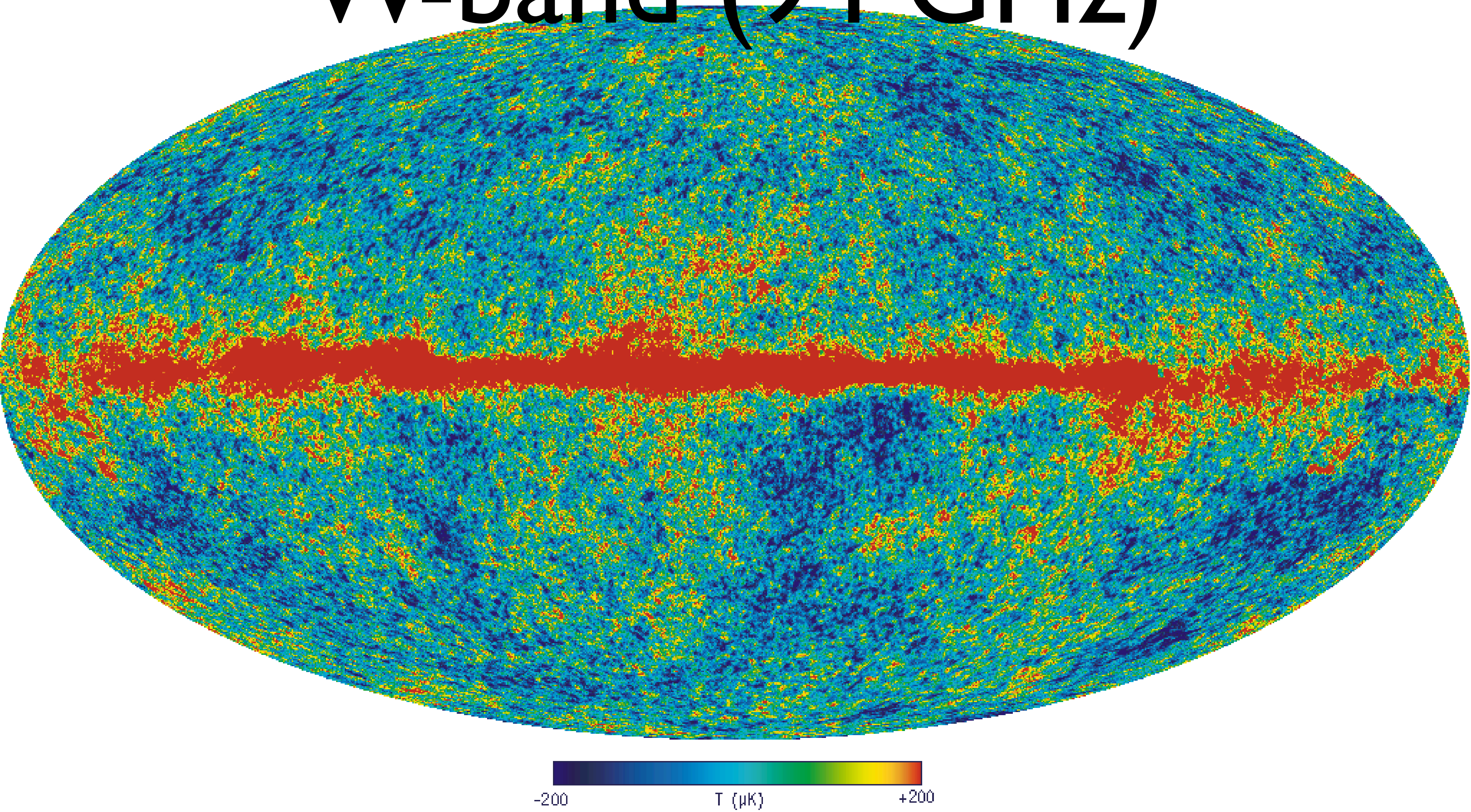
Q-band (41 GHz)

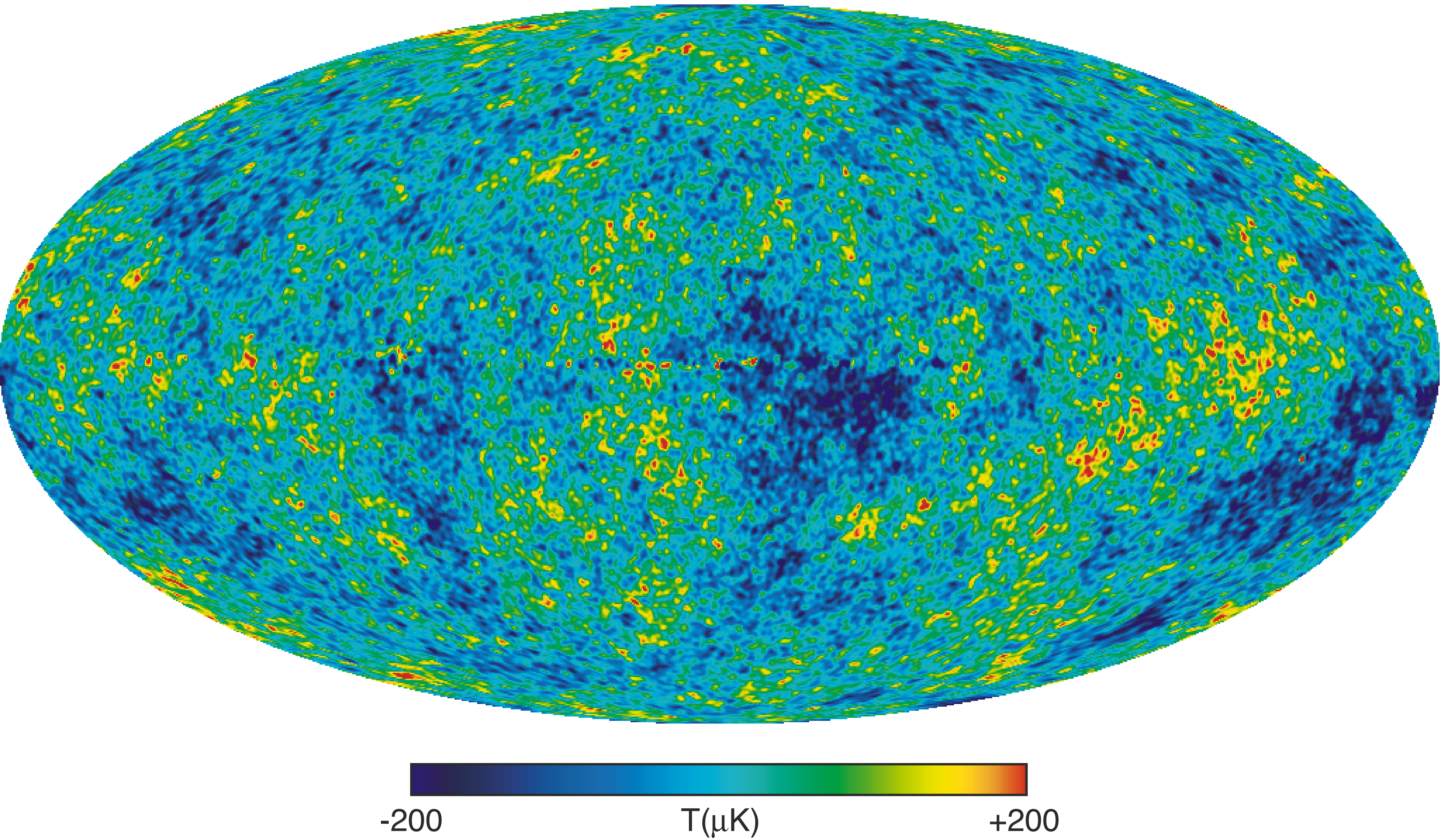


V-band (61 GHz)

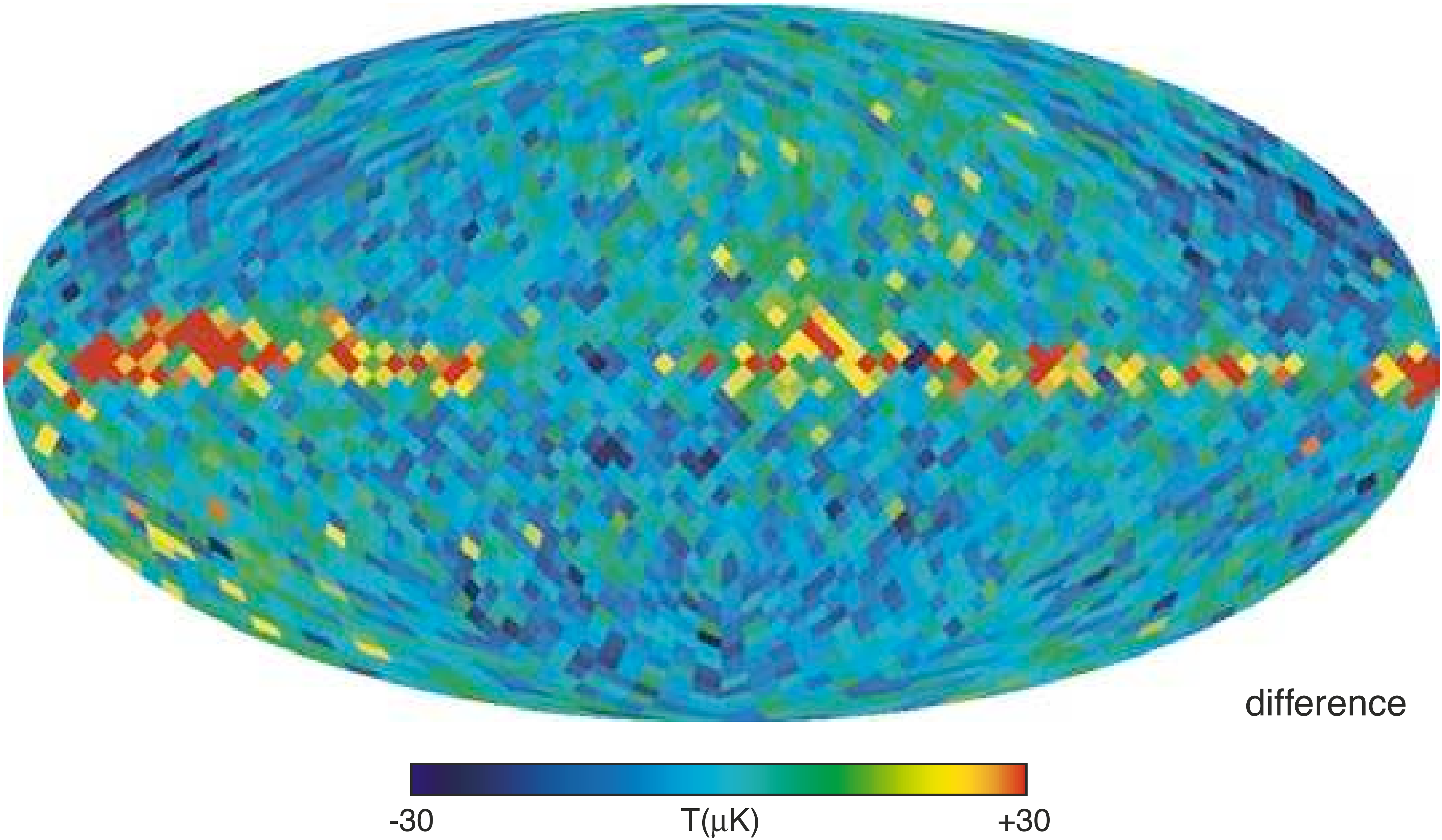


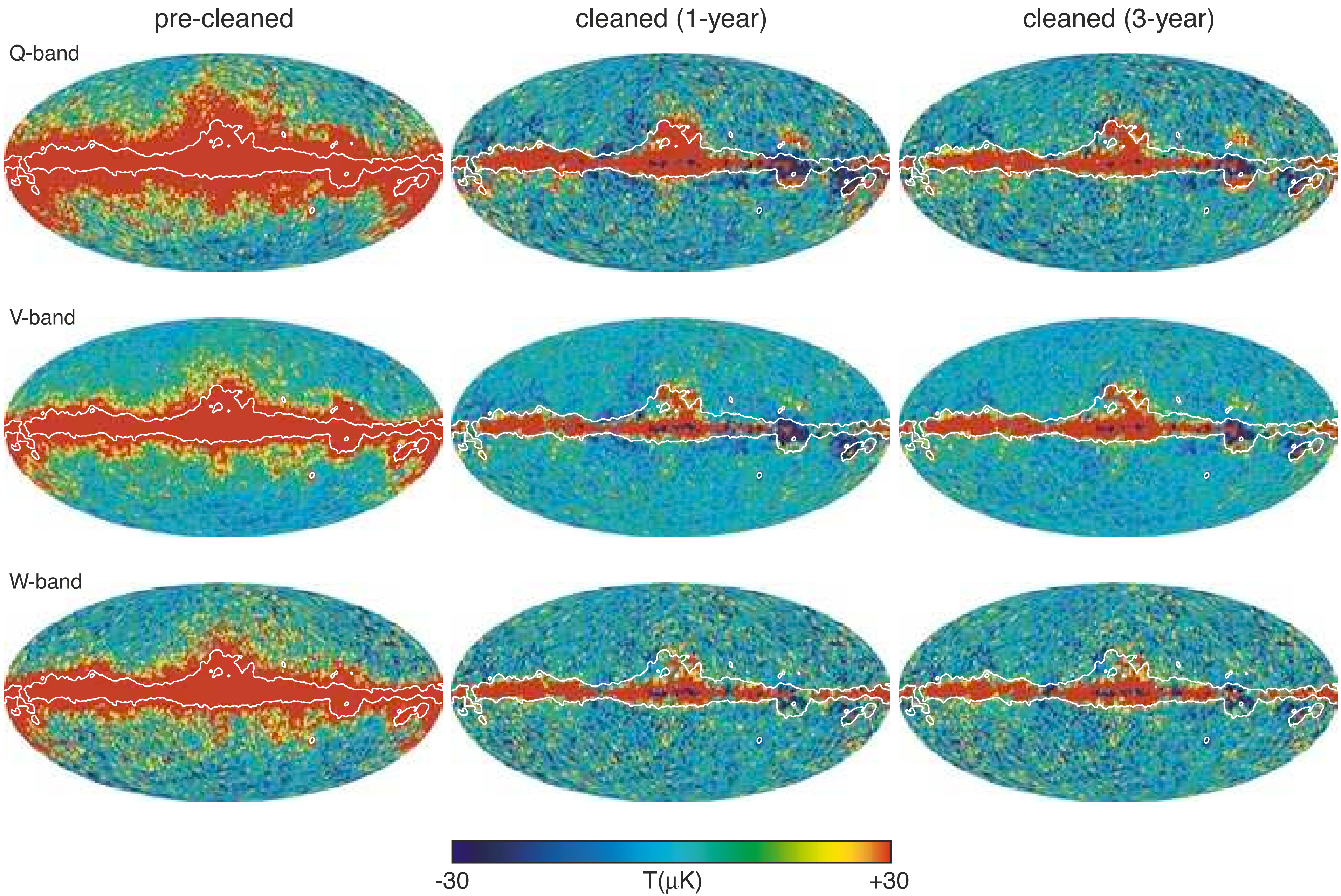
W-band (94 GHz)

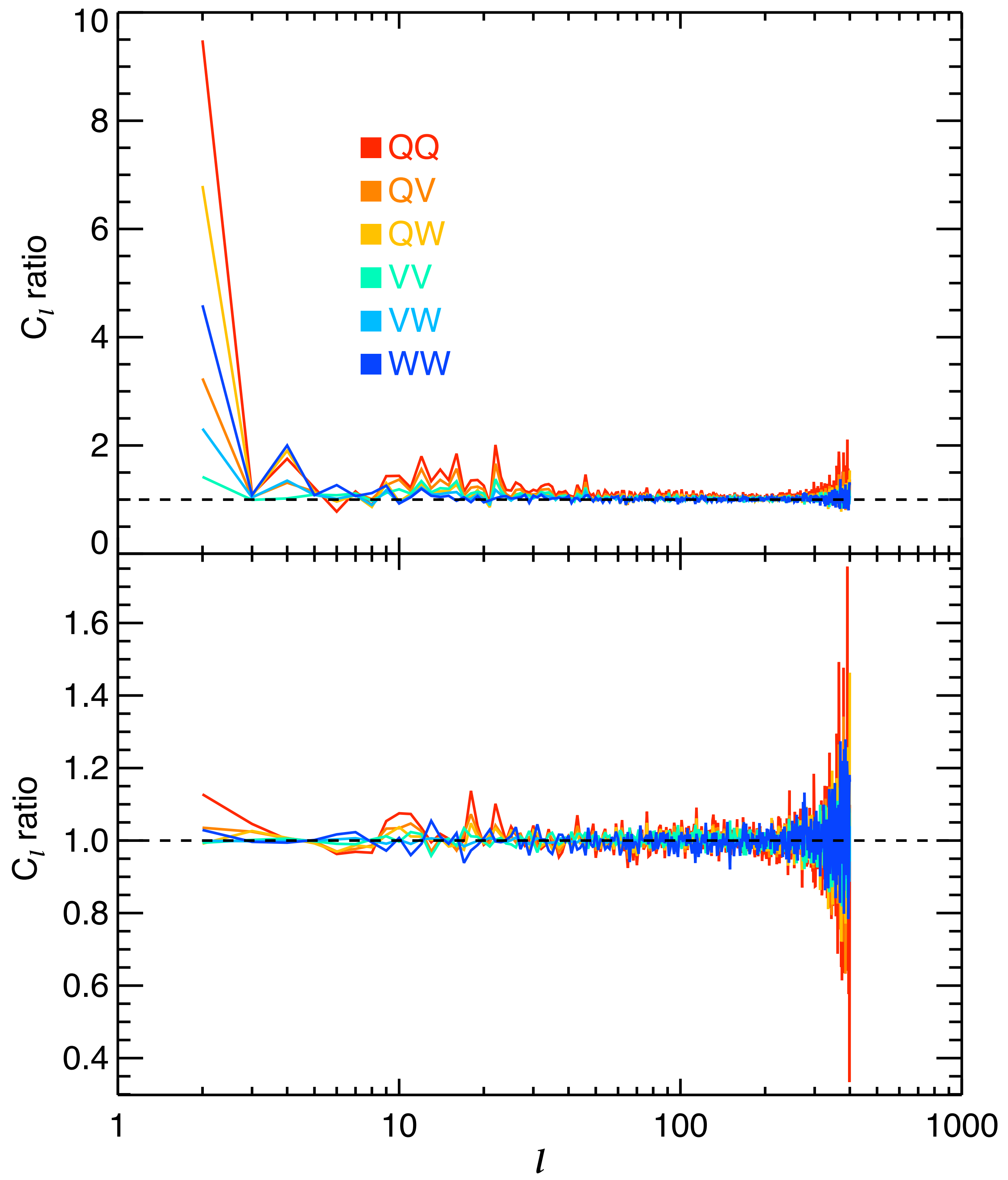



-200
T(μK)
+200

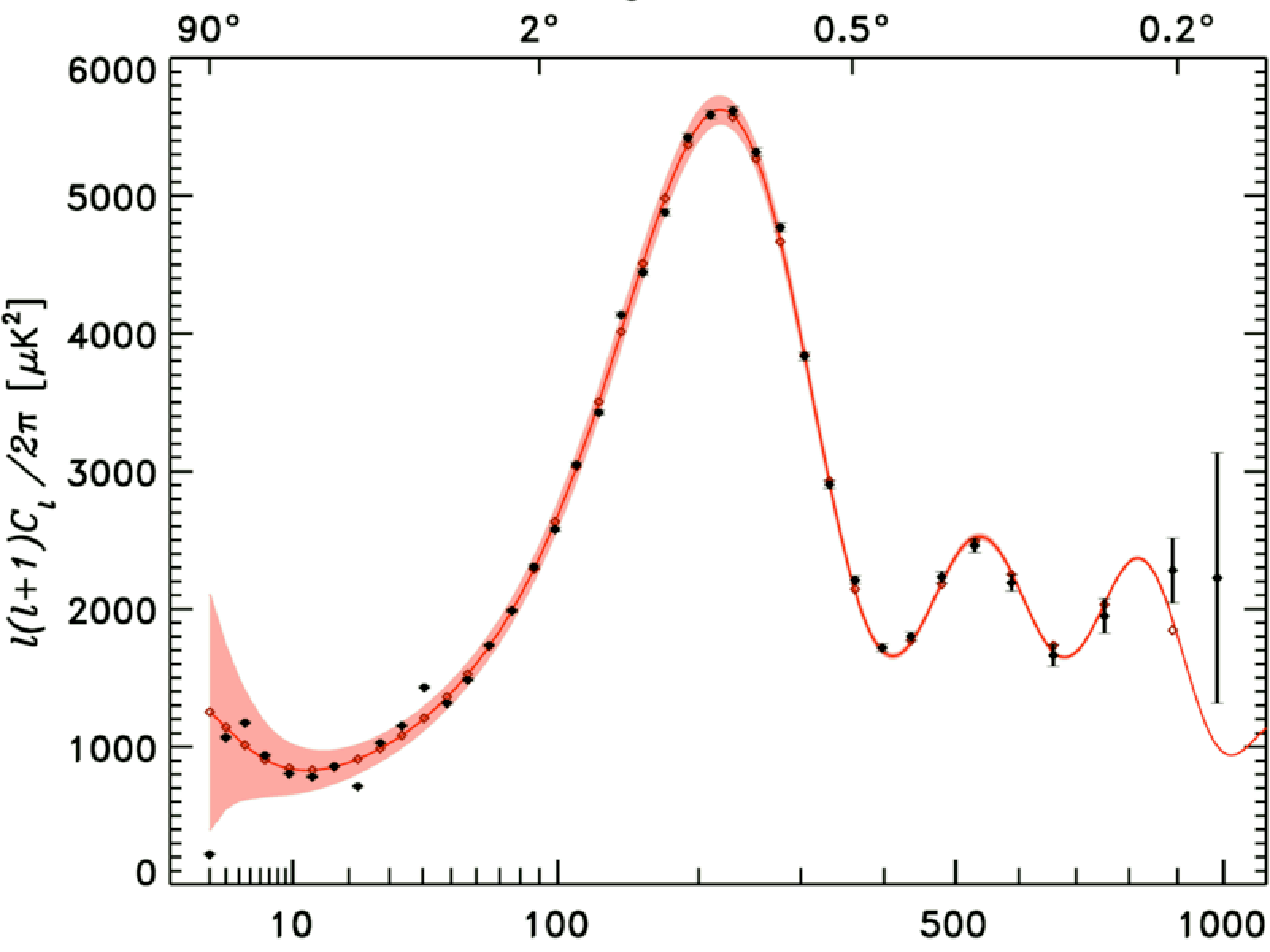
Residual FG contamination >10deg estimated to be <5uK



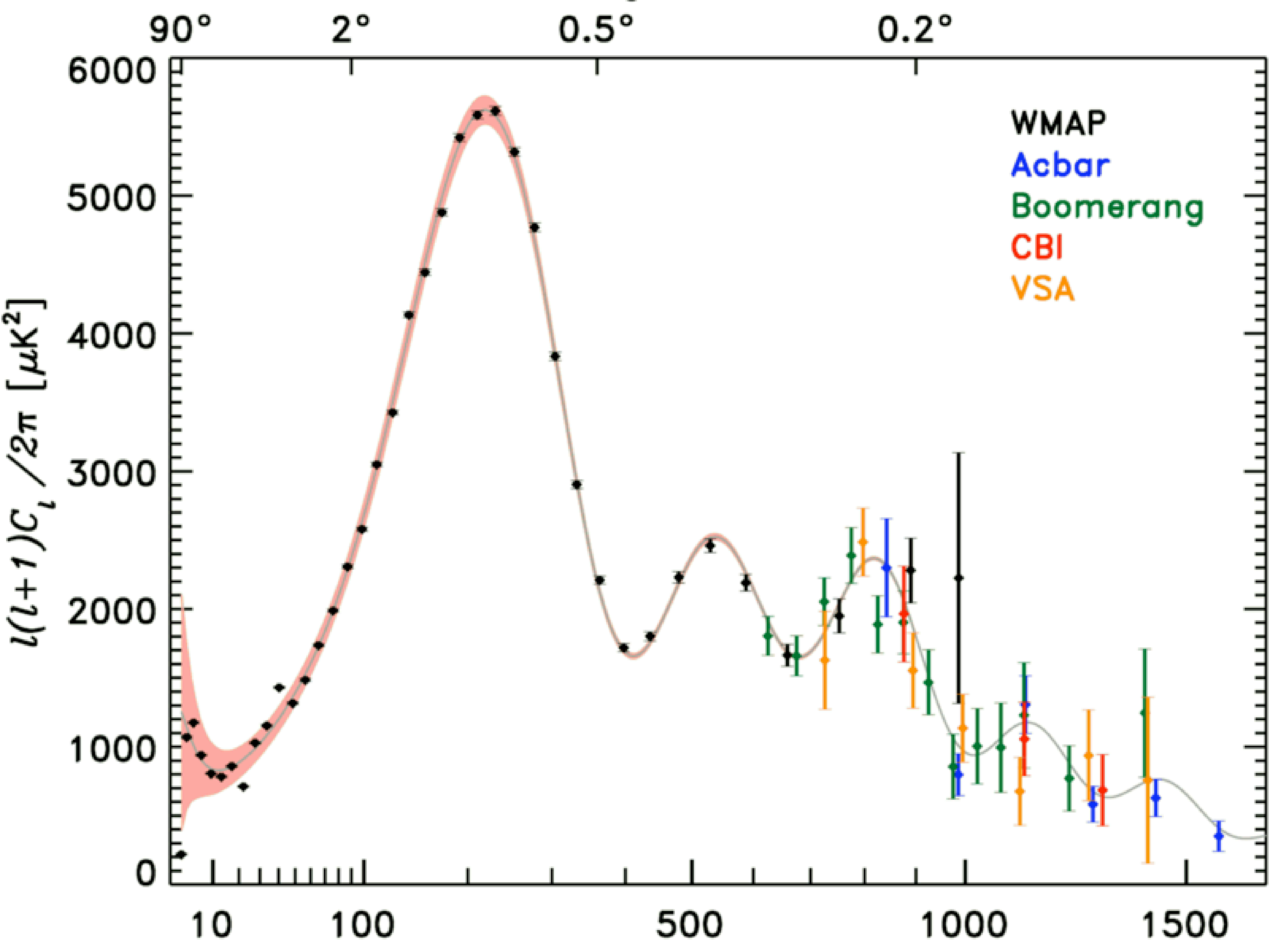

pre-cleaned
cleaned (1-year)
cleaned (3-year)
Q-band
V-band
W-band
-30
T(μK)
+30



QQ
QV
QW
VV
VW
WW
C_l ratio
C_l ratio
10
8
6
4
2
0
1.6
1.4
1.2
1.0
0.8
0.6
0.4
1
10
100
1000
l

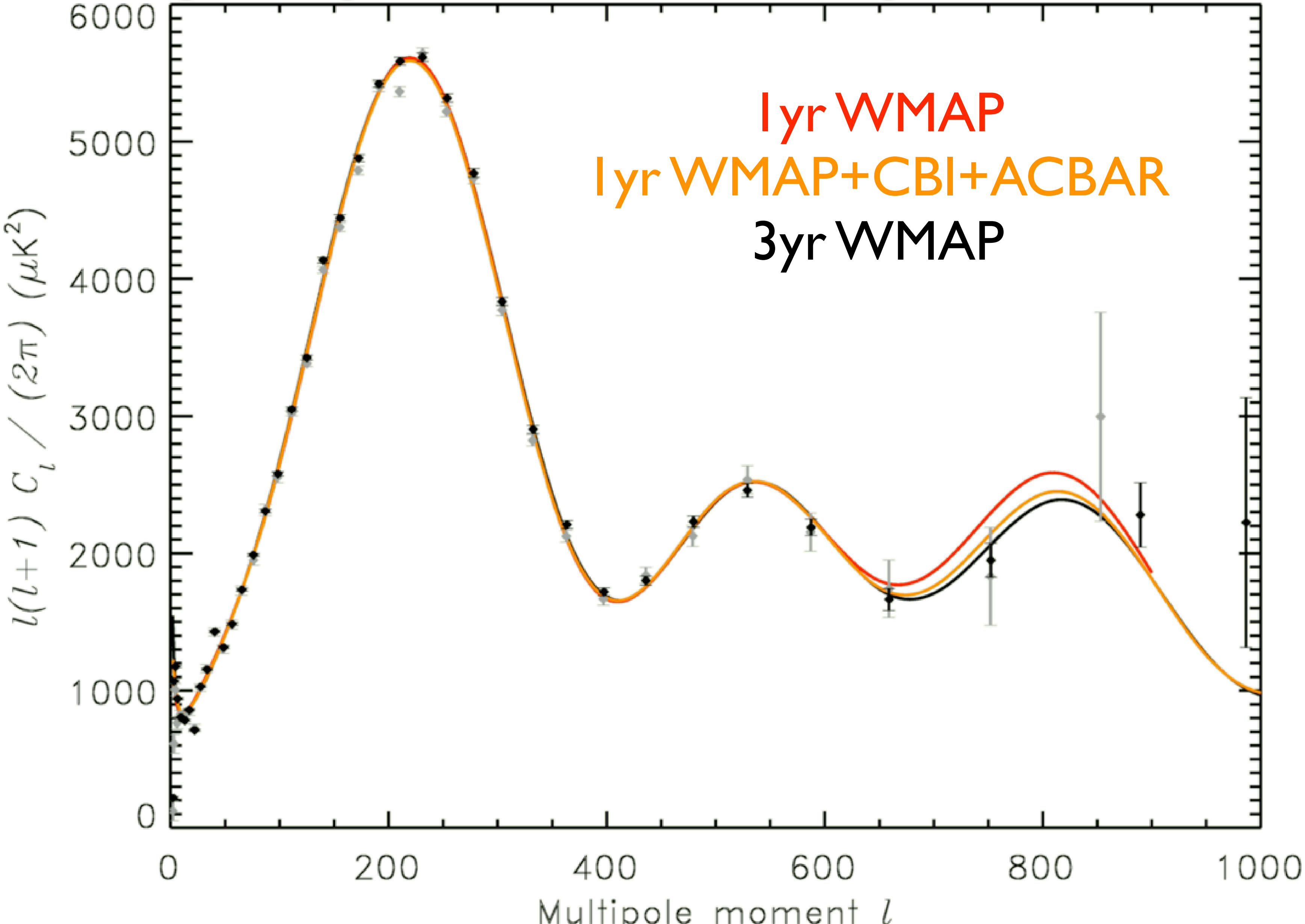


90°
2°
0.5°
0.2°
6000
5000
4000
3000
2000
1000
0
l(l+1)C_l /2π [μK^2]
10
100
500
1000

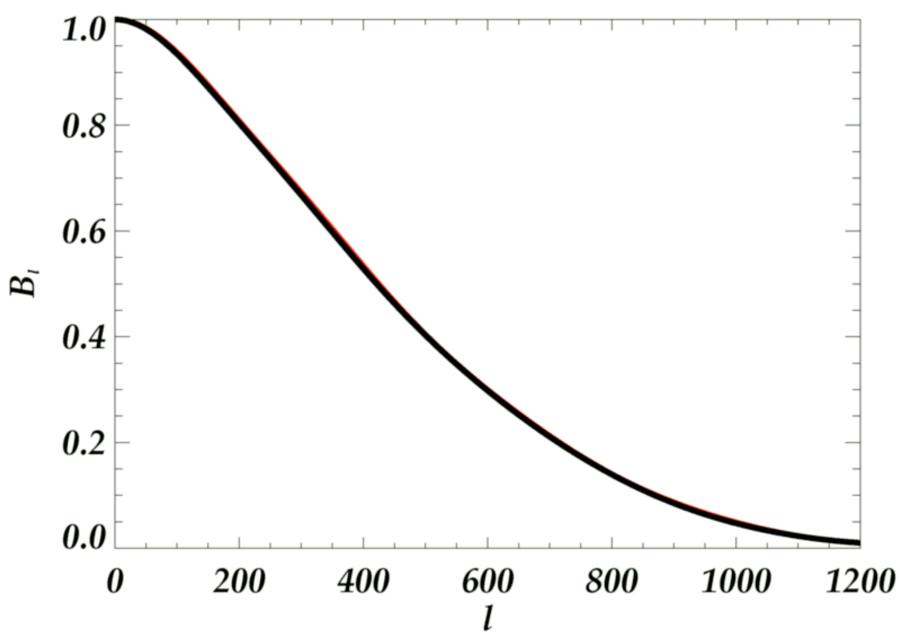


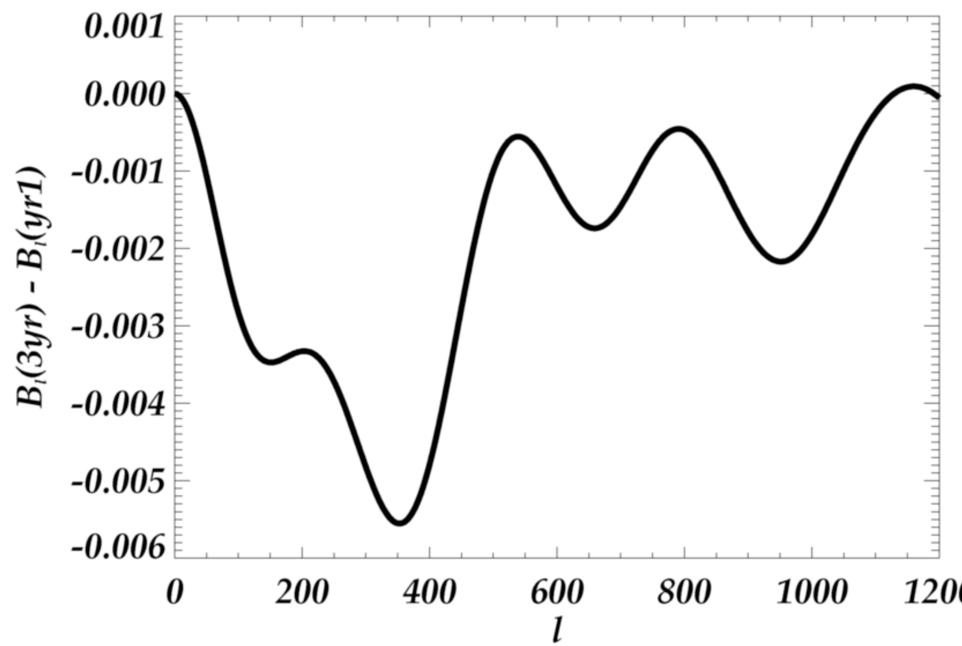
90°
2°
0.5°
0.2°
6000
5000
4000
3000
2000
1000
0
l(l+1)C_l /2π [μK²]
10
100
500
1000
1500
WMAP
Acbar
Boomerang
CBI
VSA

1yr/3yr TT C_l comparison

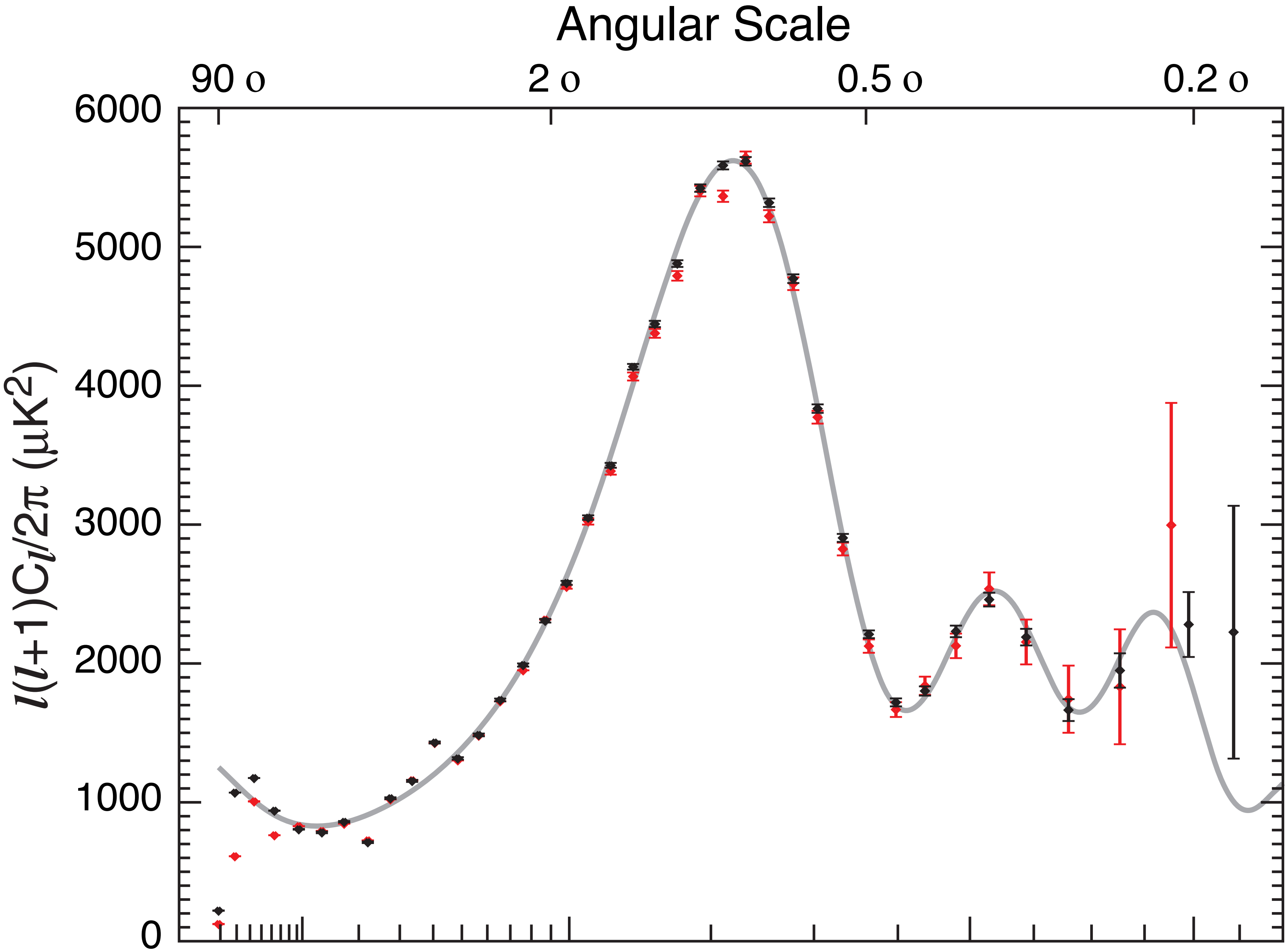


1yr/3yr Beam difference

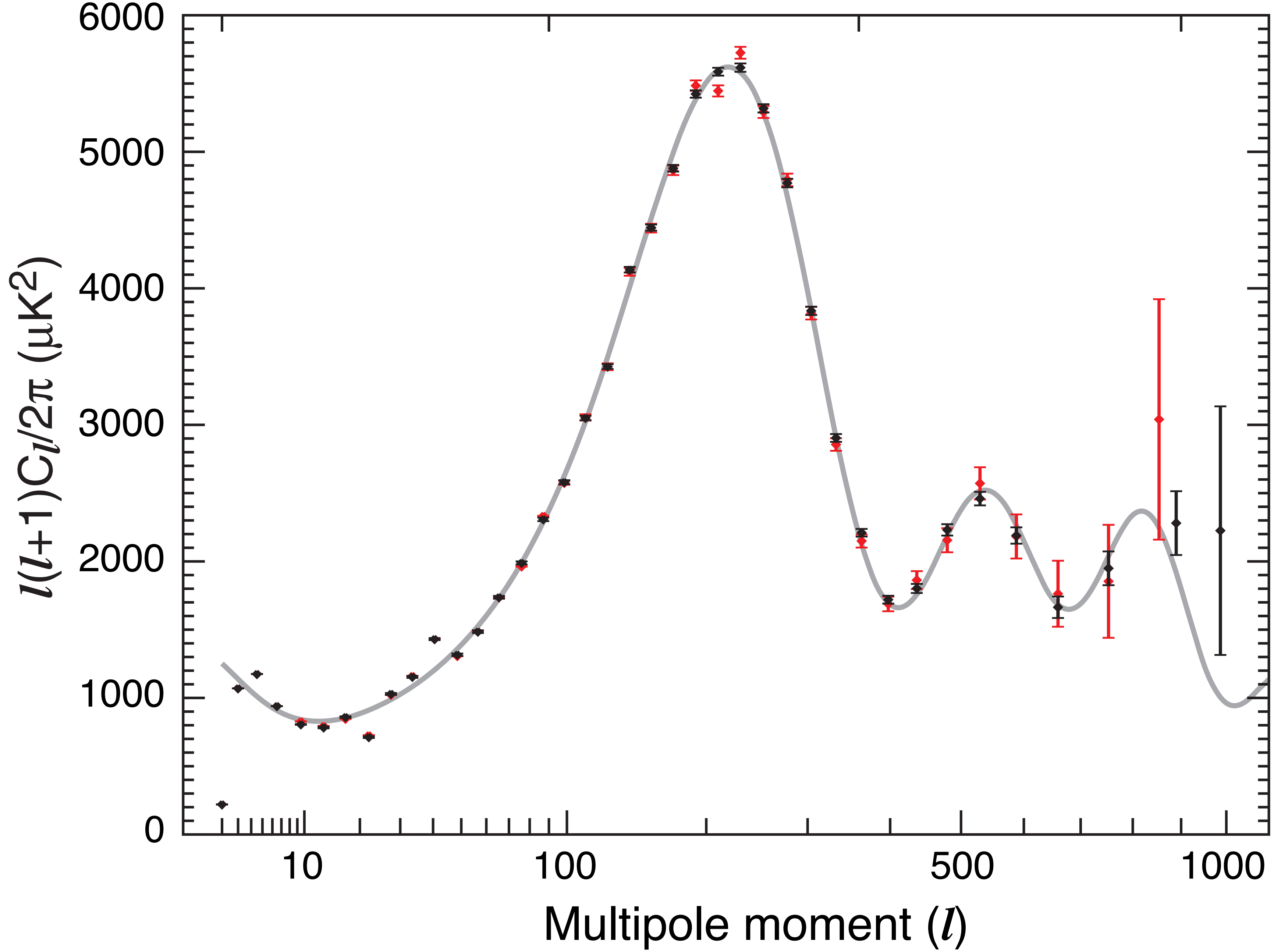




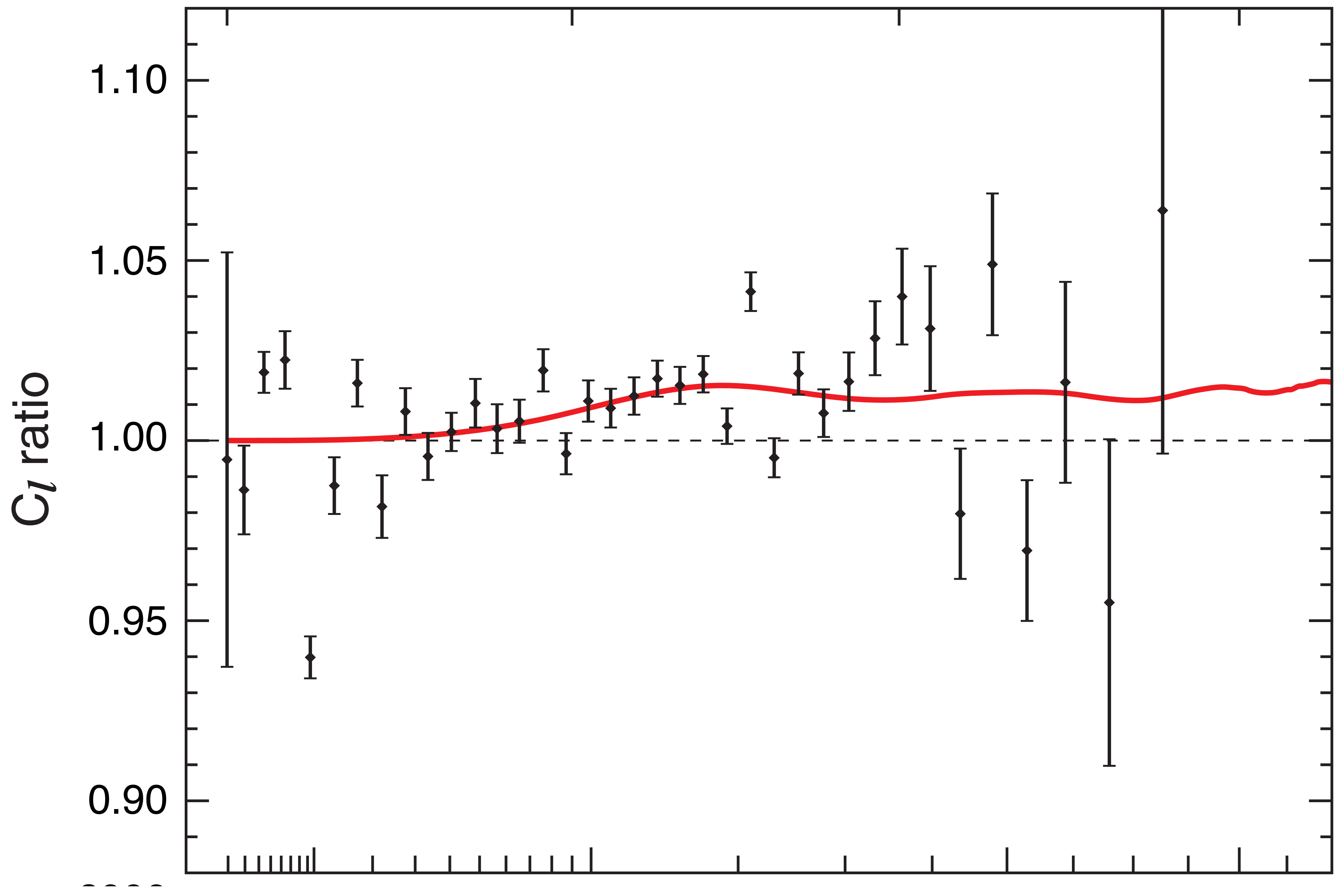
- 3yr beam solid angles are ~1% larger than 1yr
- Leads to a ~1.5% reduction in the VW window function for 200<l<800
- Change is consistent with 1yr beam uncertainties

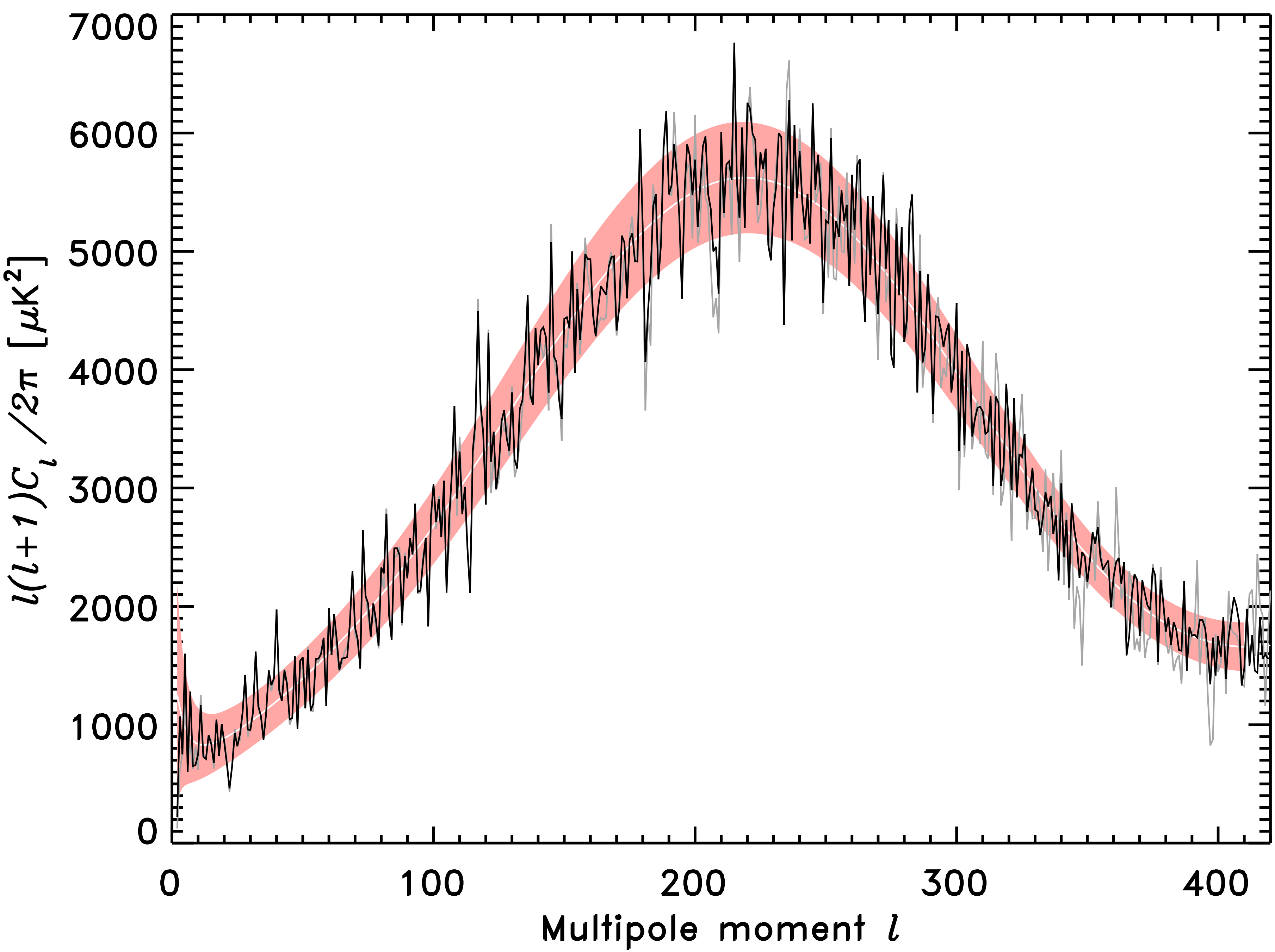


Angular Scale
90 o
2 o
0.5 o
0.2 o
6000
5000
4000
3000
2000
1000
0
l(l+1)Cl/2π (μK2)

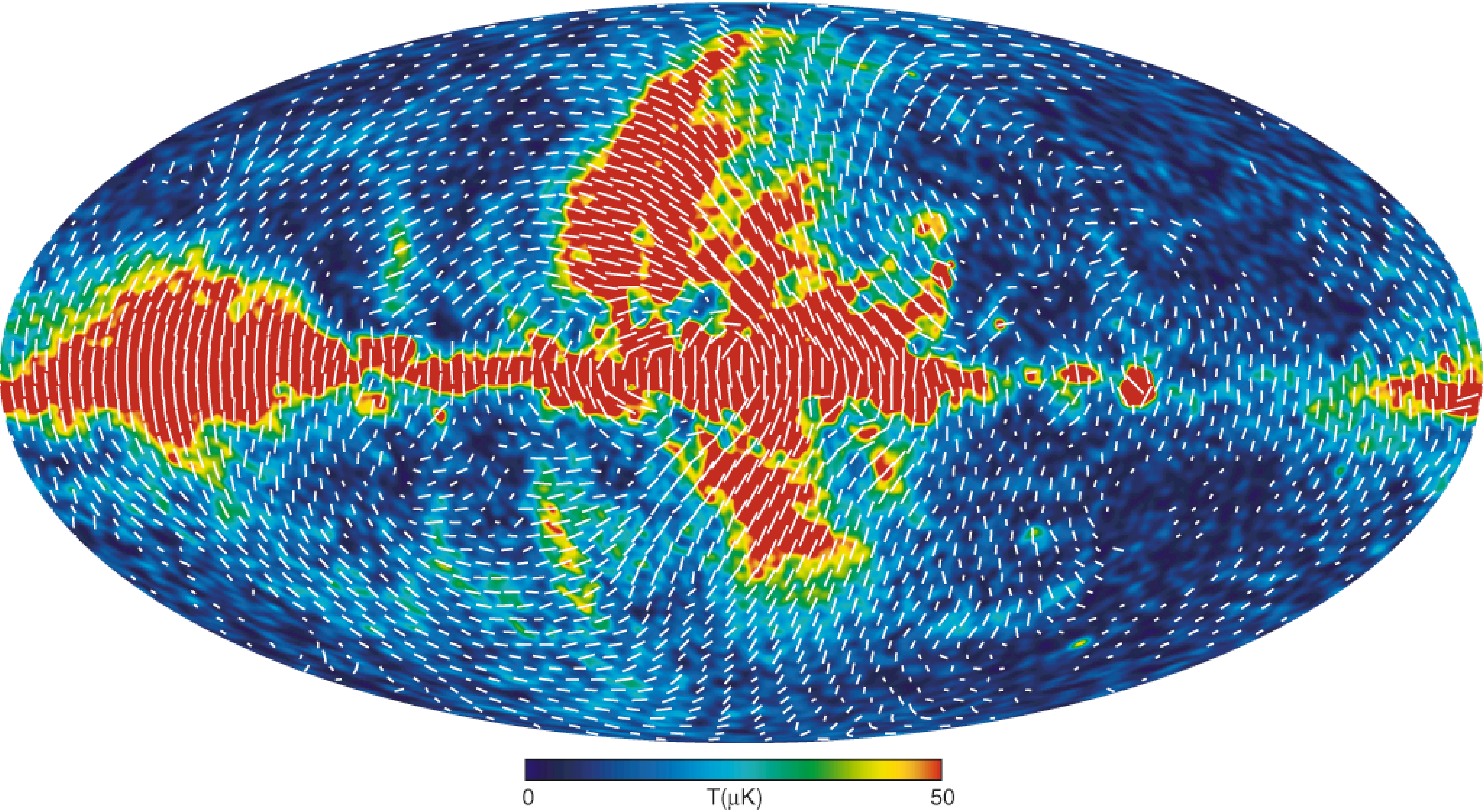


6000
5000
4000
3000
2000
1000
0
10
100
500
1000
Multipole moment (l)
l(l+1)Cl/2π (μK²)

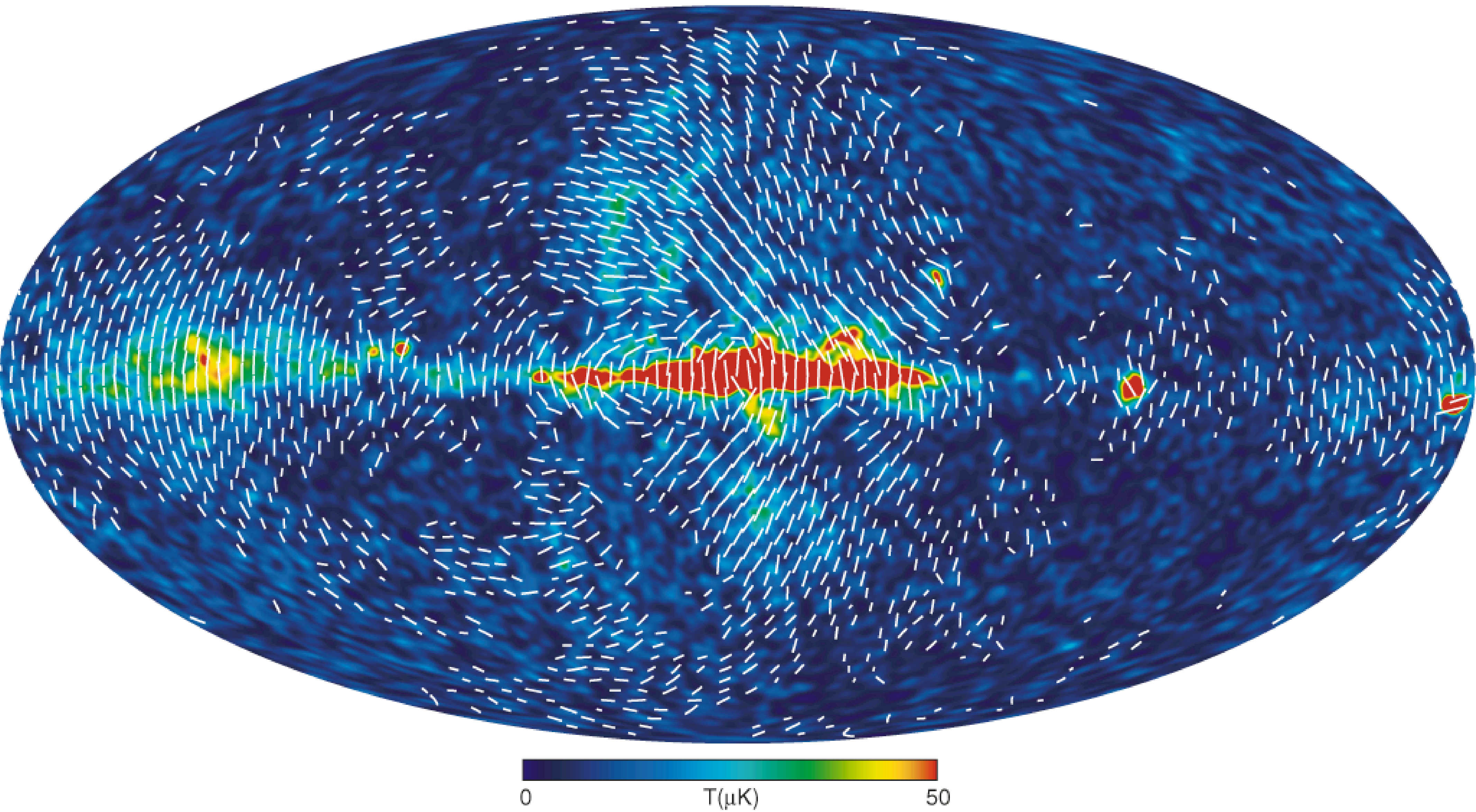

1.10
1.05
1.00
0.95
0.90
C_l ratio


7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
Multipole moment l
l(l+1)C_l /2π [μK²]

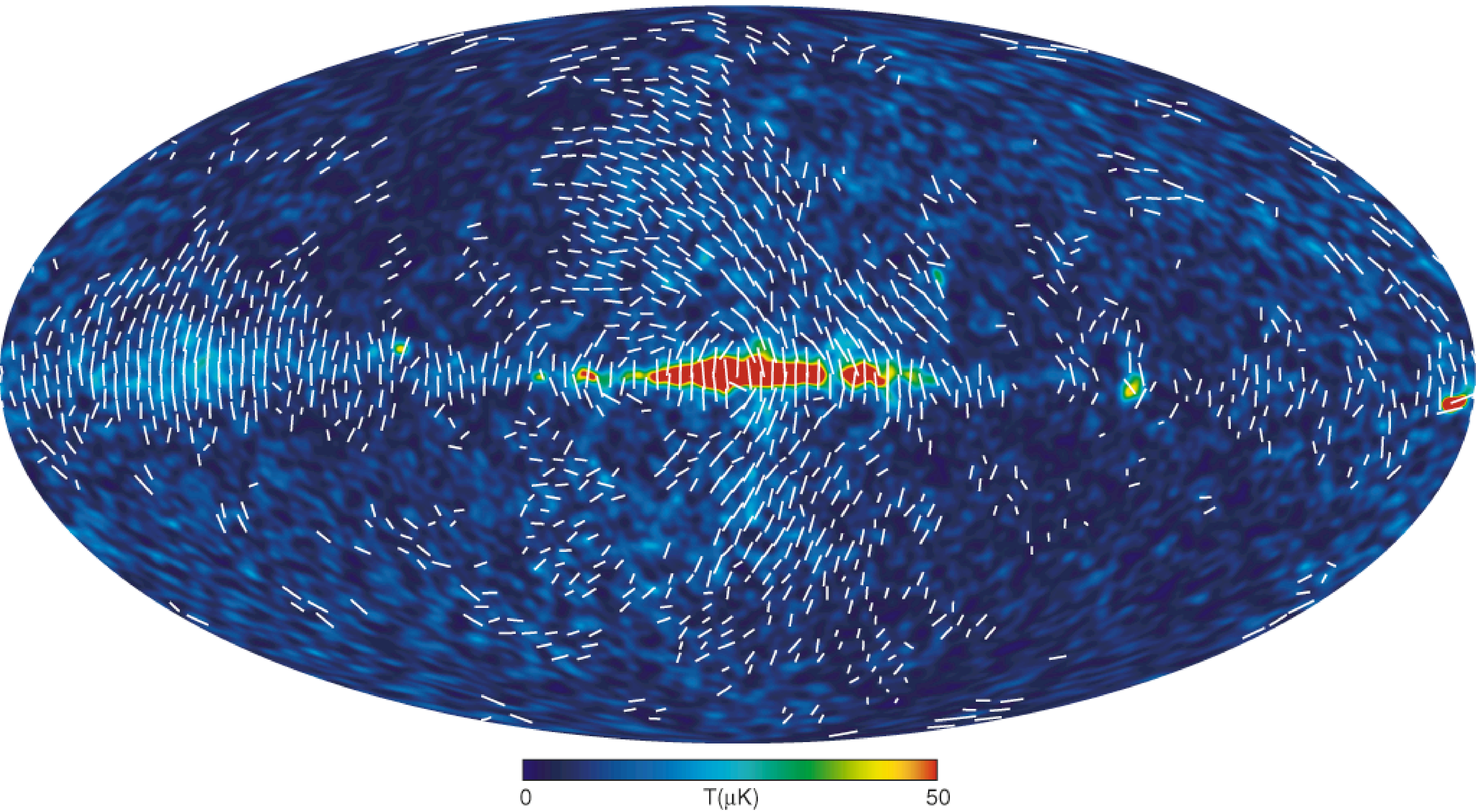
K-band polarization (23GHz)



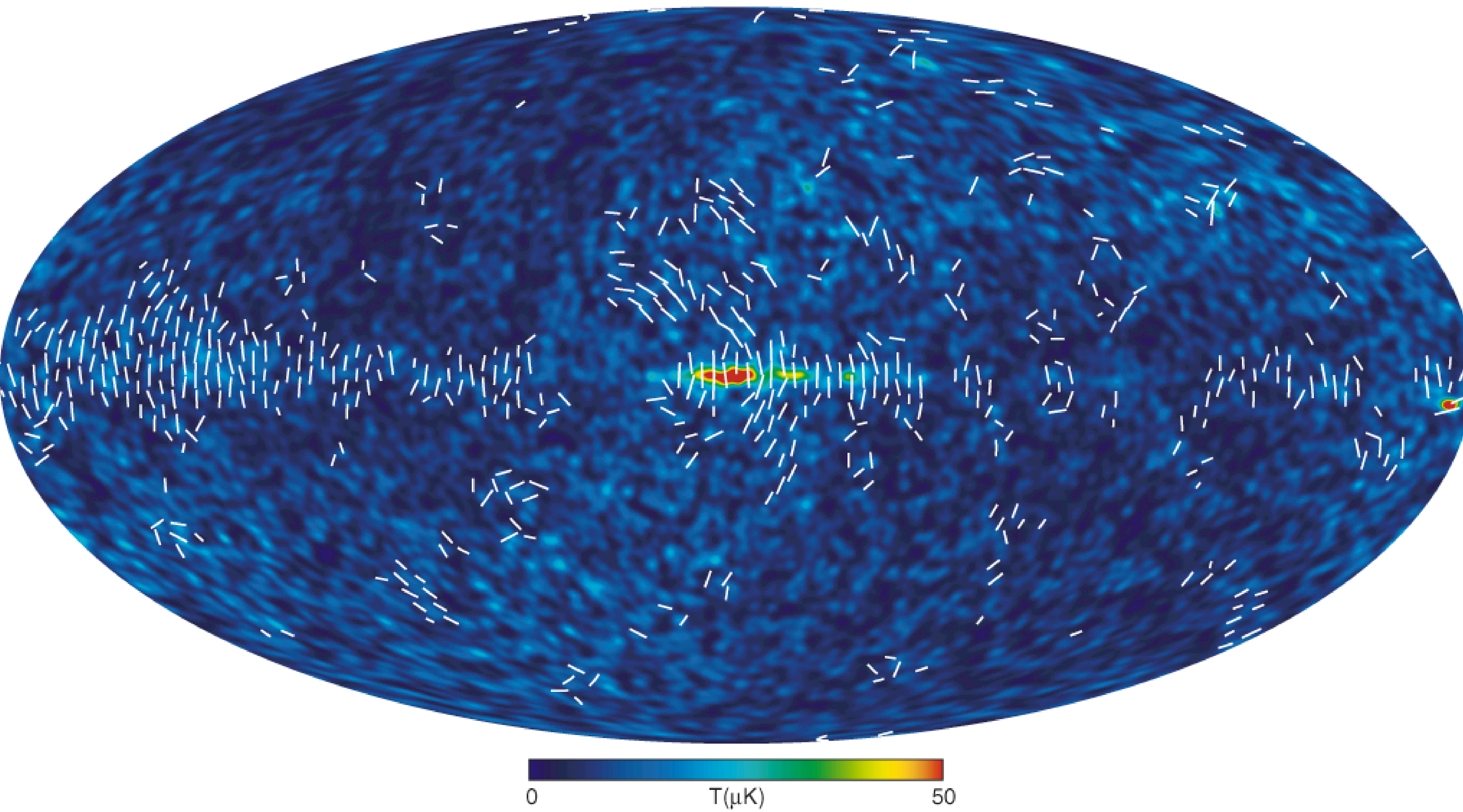
Ka-band polarization (33GHz)



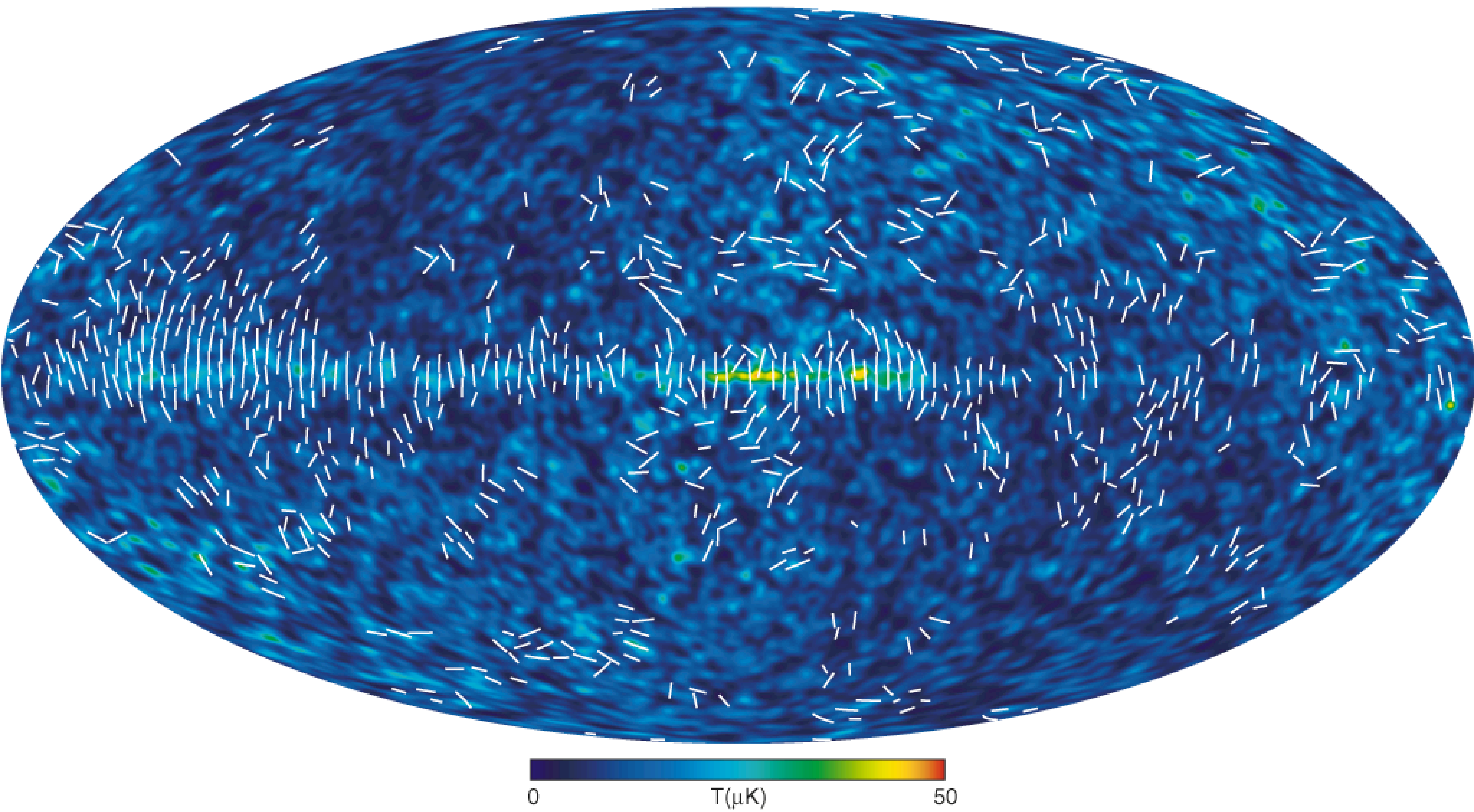
Q-band polarization (41GHz)

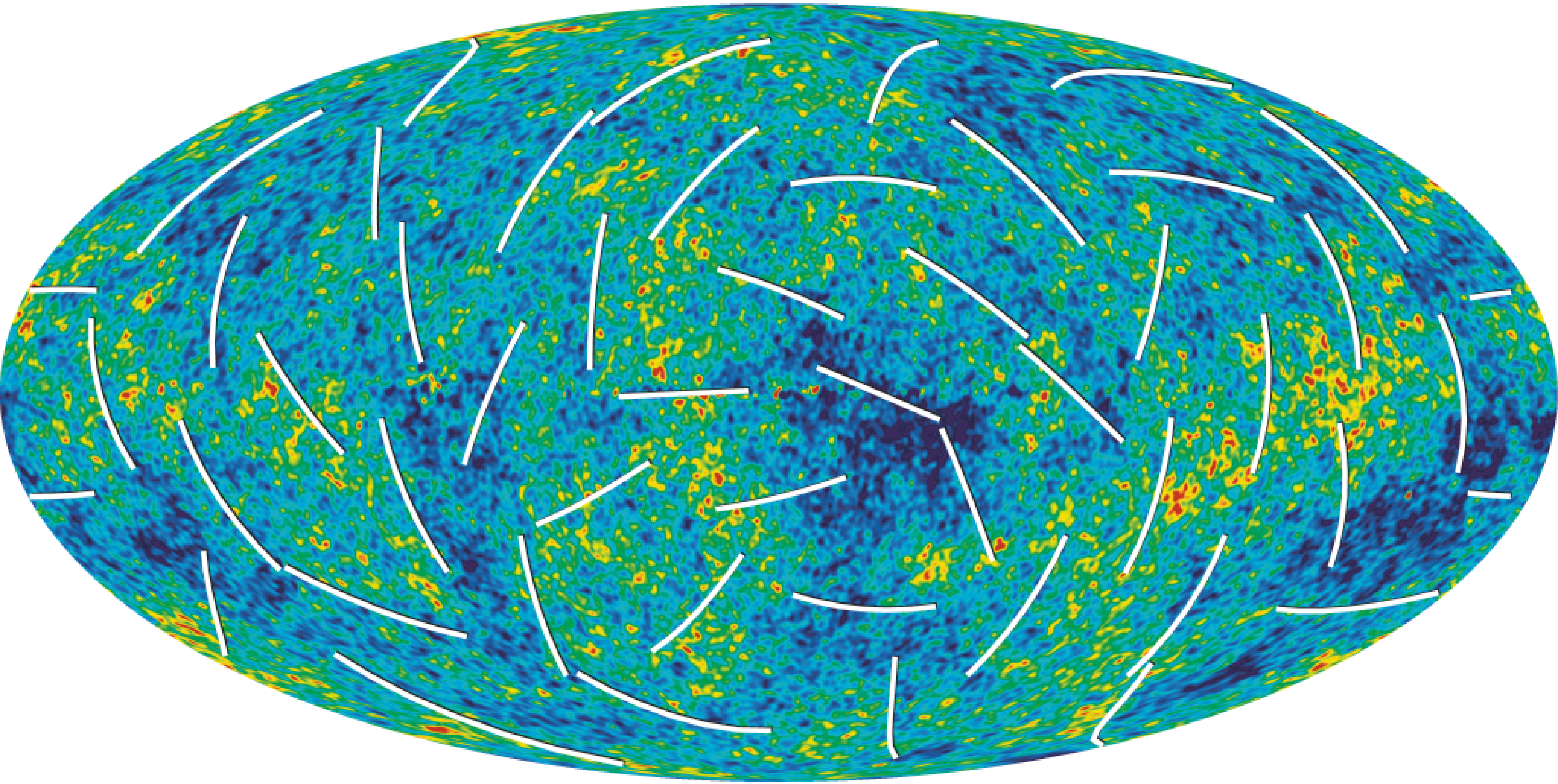


V-band polarization (61GHz)

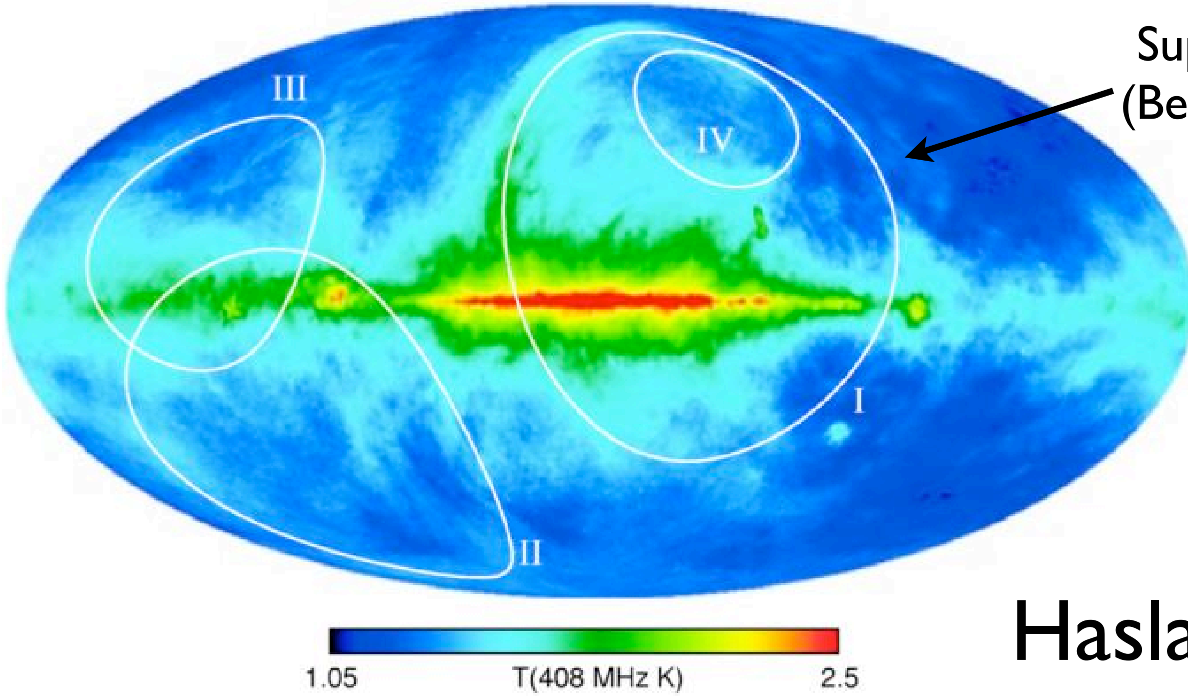


W-band polarization (94Ghz)

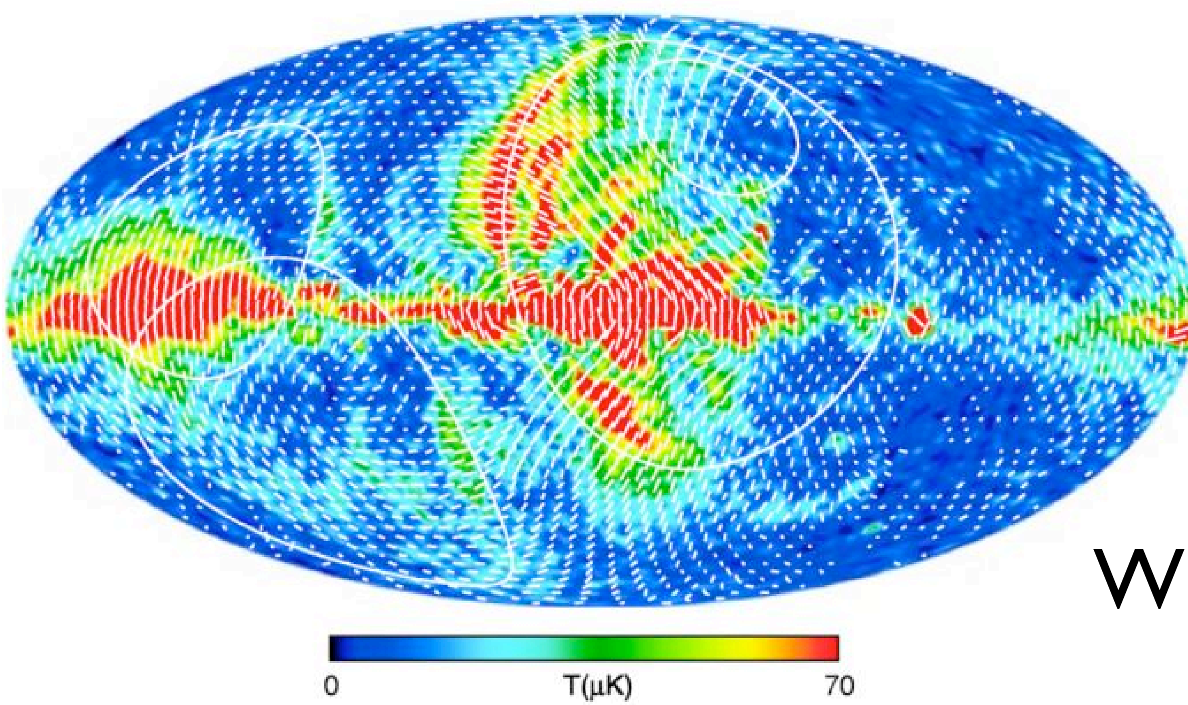




Supernova radio loops
(Berkhuijsen et al. 1971)

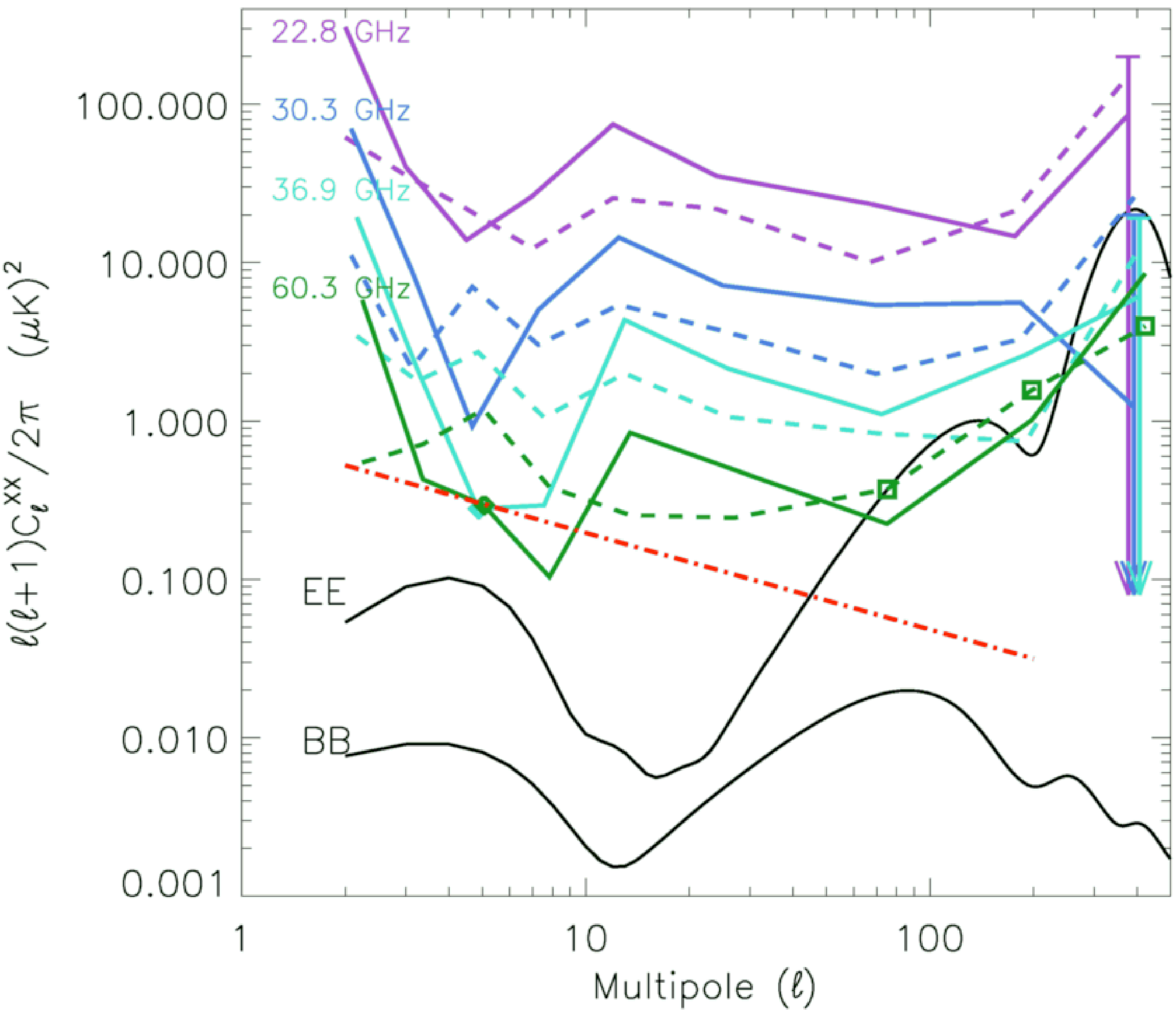


Haslam 408 MHz

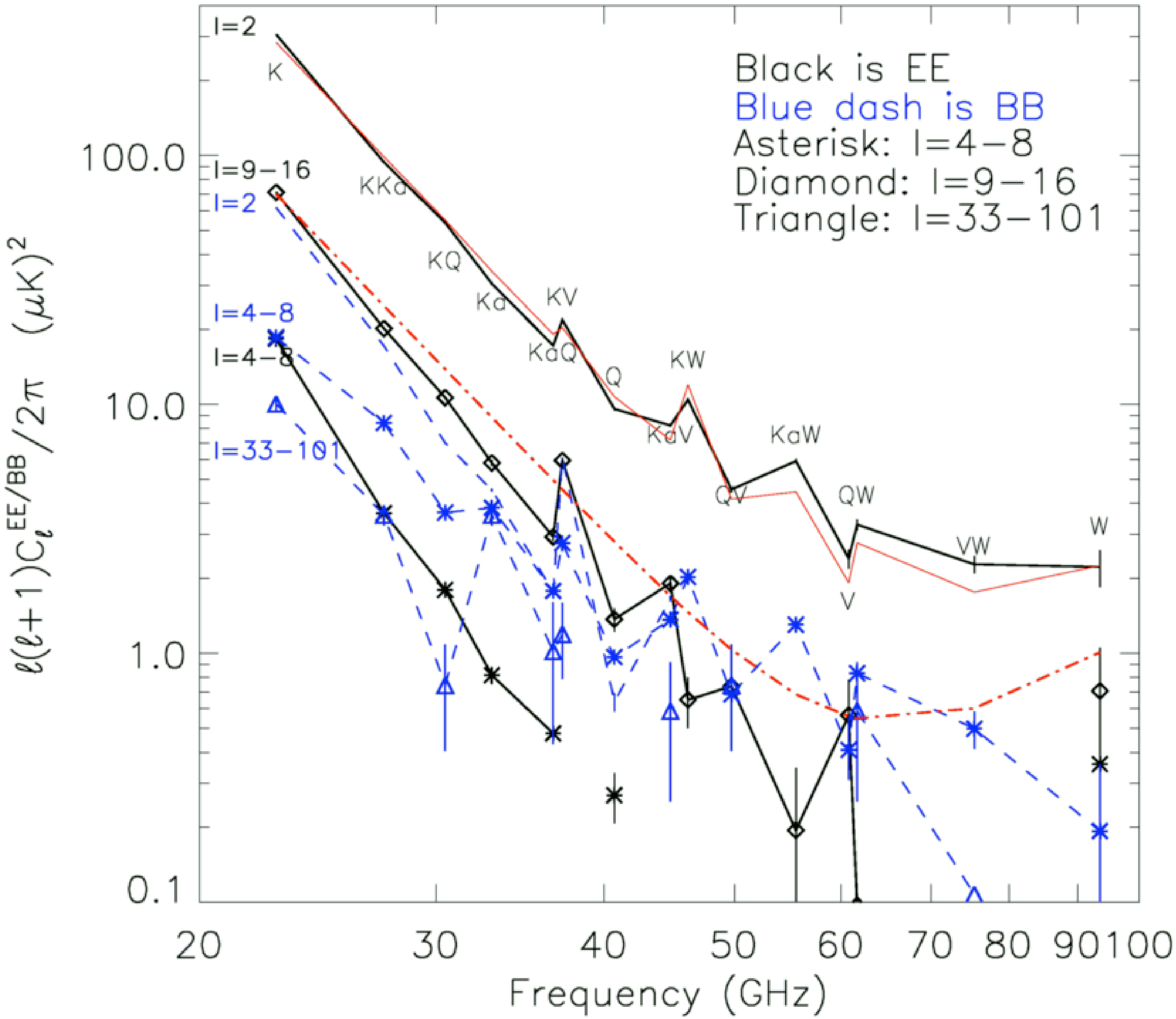


WMAP K-band

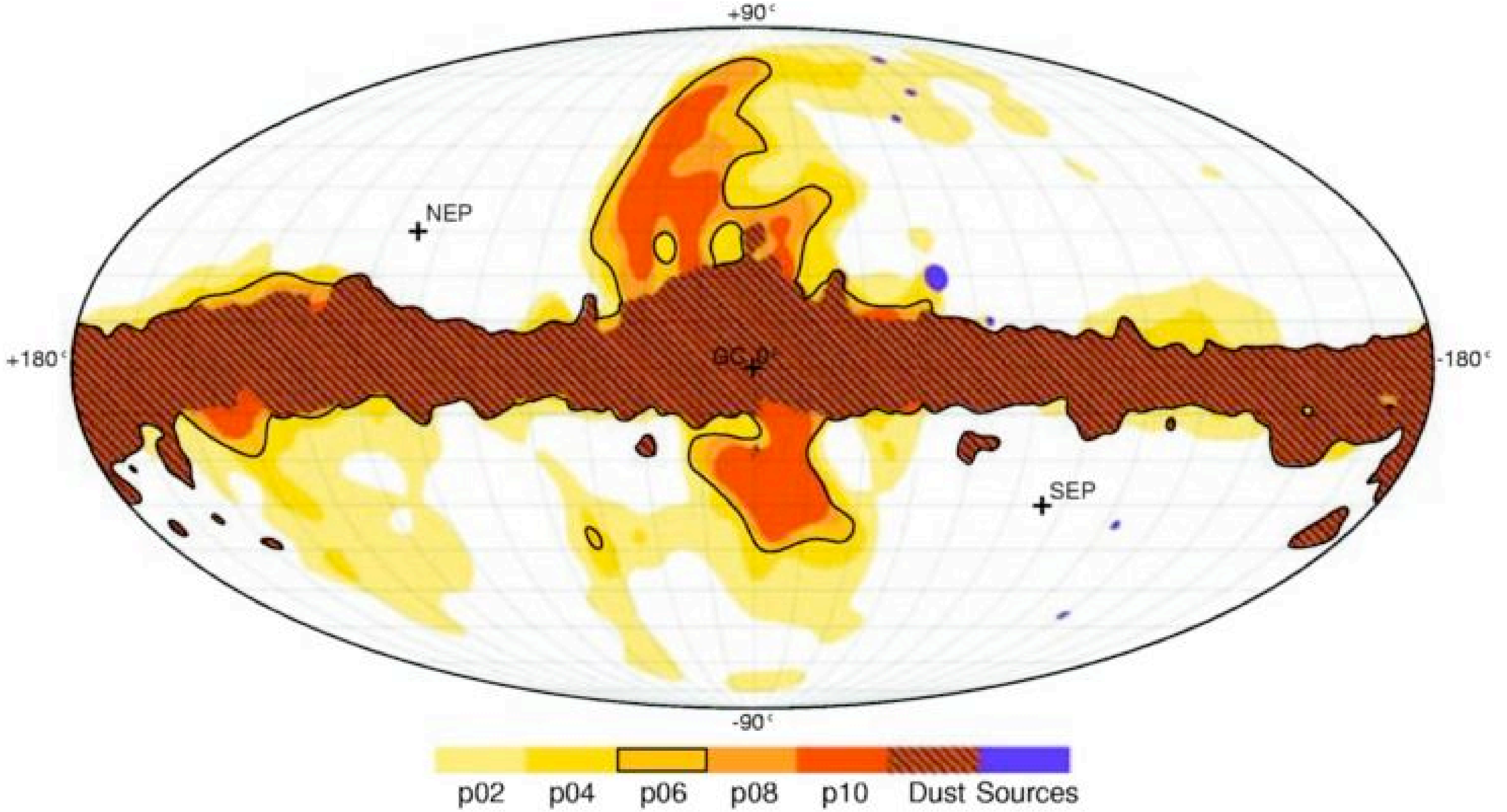
Raw EE/BB spectra



Raw EE/BB freq spectrum



Polarization mask



Galactic modeling

Magnetic field

$$\mathbf{B}(r,\phi,z) = B_0[\cos\psi(r)\cos\chi(z)\hat{r} + \sin\psi(r)\cos\chi(z)\hat{\phi} + \sin\chi(z)\hat{z}]$$

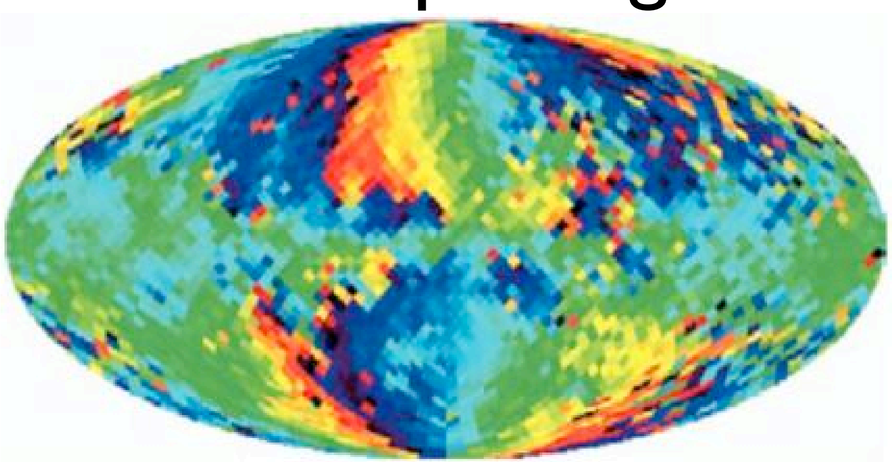
+

Electron distribution

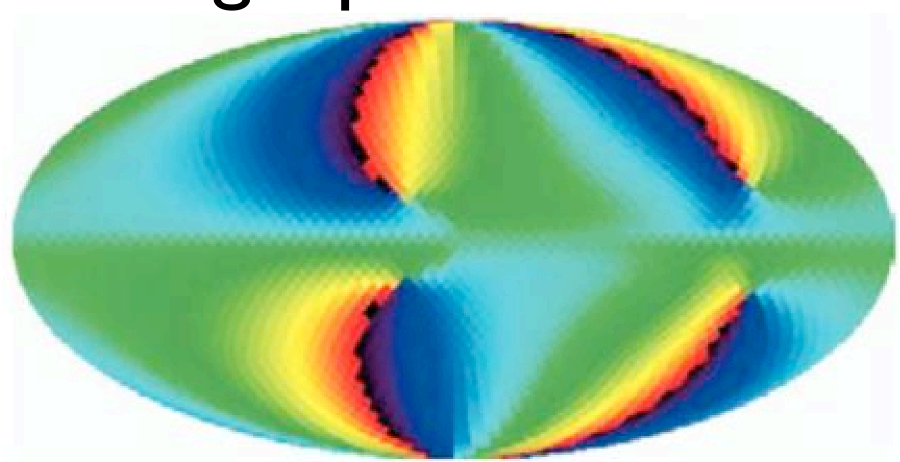
$$n_e = n_0 \exp(-r/h_r)\mathrm{sech}^2(z/h_d).$$

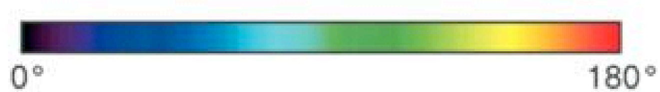
=

K-band pol angle



angle prediction

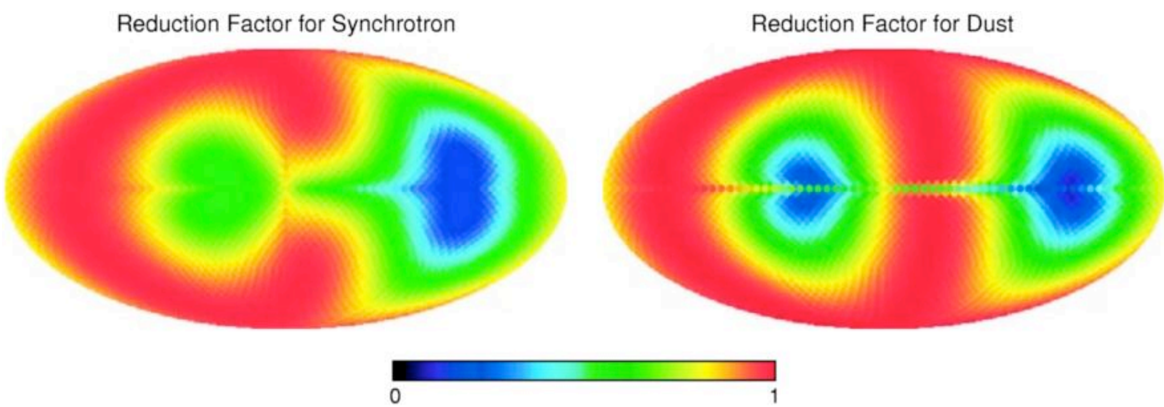




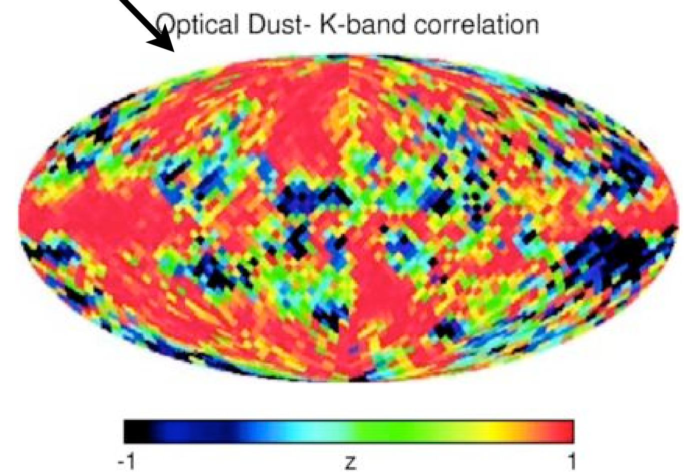
Polarized dust template

Use galactic model to create polarized dust template from dust intensity map

$$Q_{dust}(\nu) = I_{dust}(\hat{n}) \Pi_d \, g_{dust}(\hat{n}) \cos(2\gamma_{dust})$$
$$U_{dust}(\nu) = I_{dust}(\hat{n}) \Pi_d \, g_{dust}(\hat{n}) \sin(2\gamma_{dust})$$

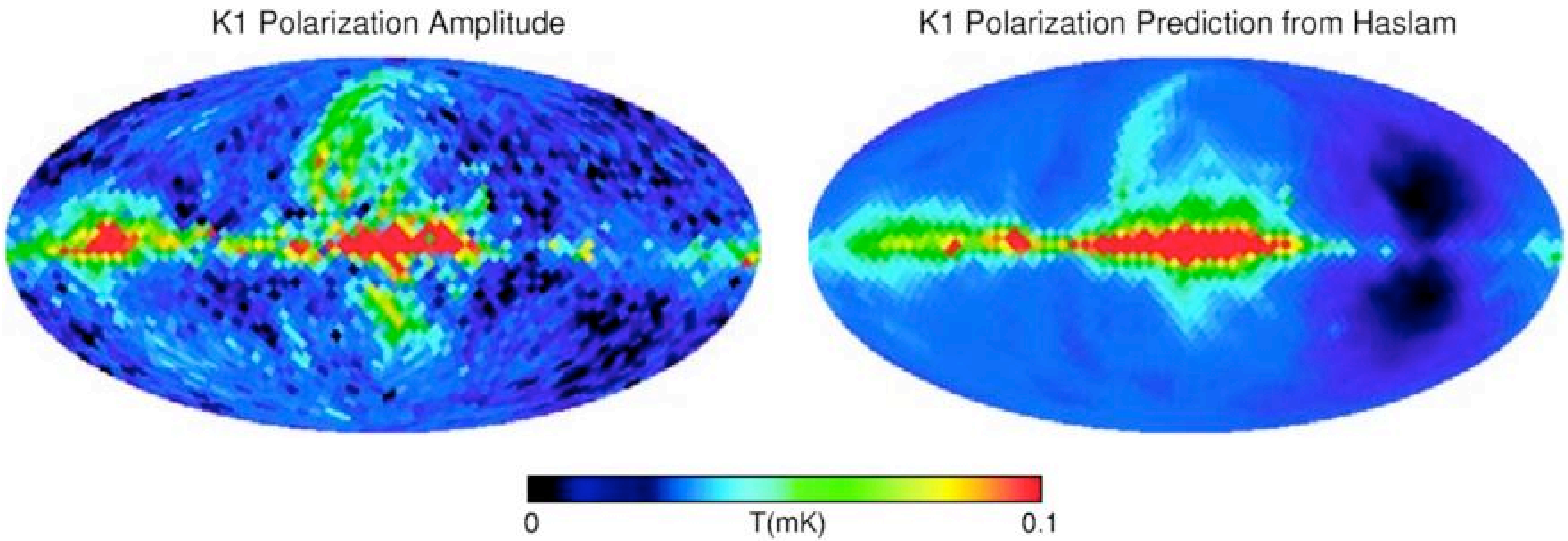


suppression factor P/I predicted by the model

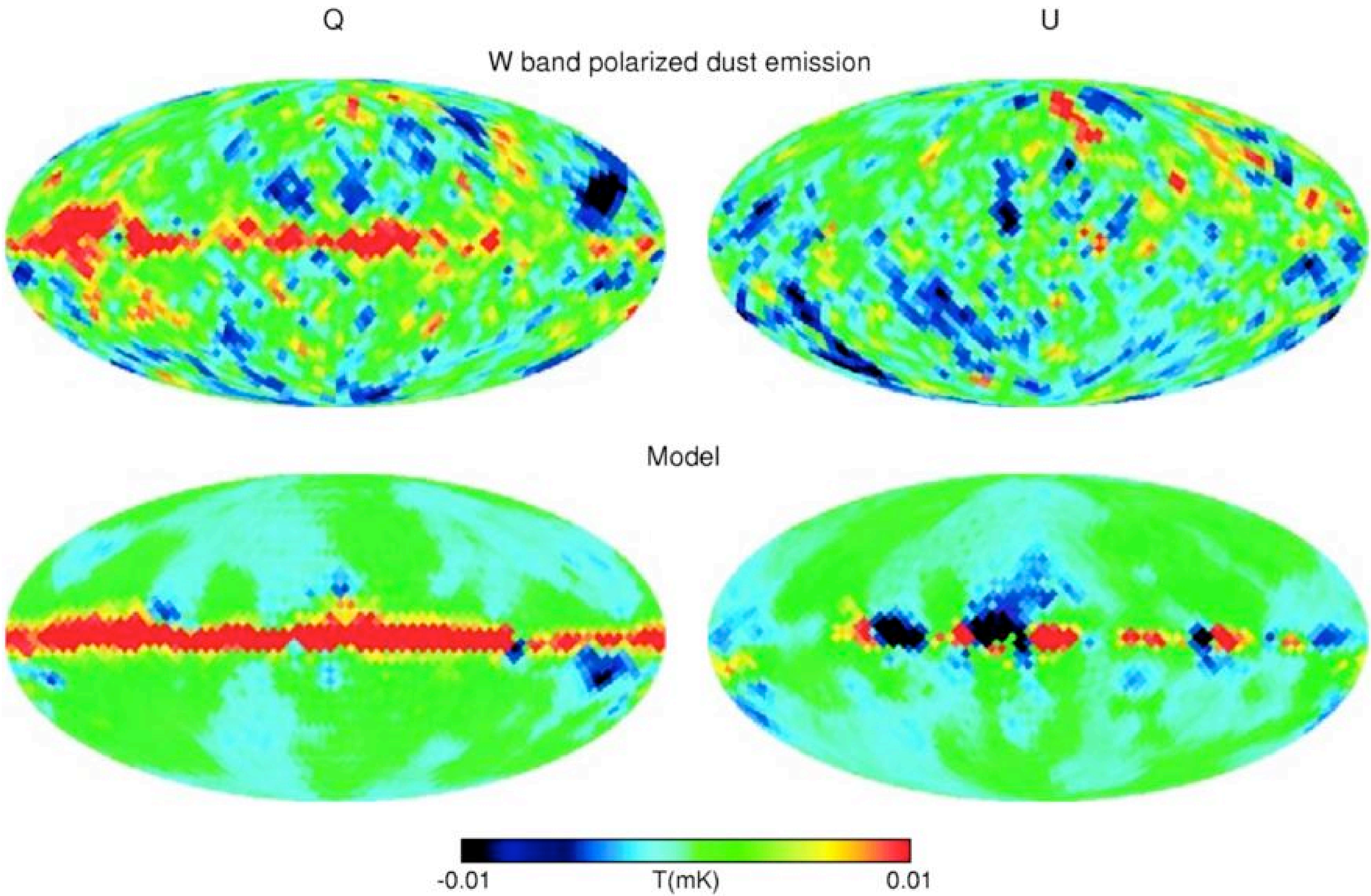


Dust directions from starlight polarization data

Polarized synchrotron prediction



Polarized dust prediction



Foreground cleaning

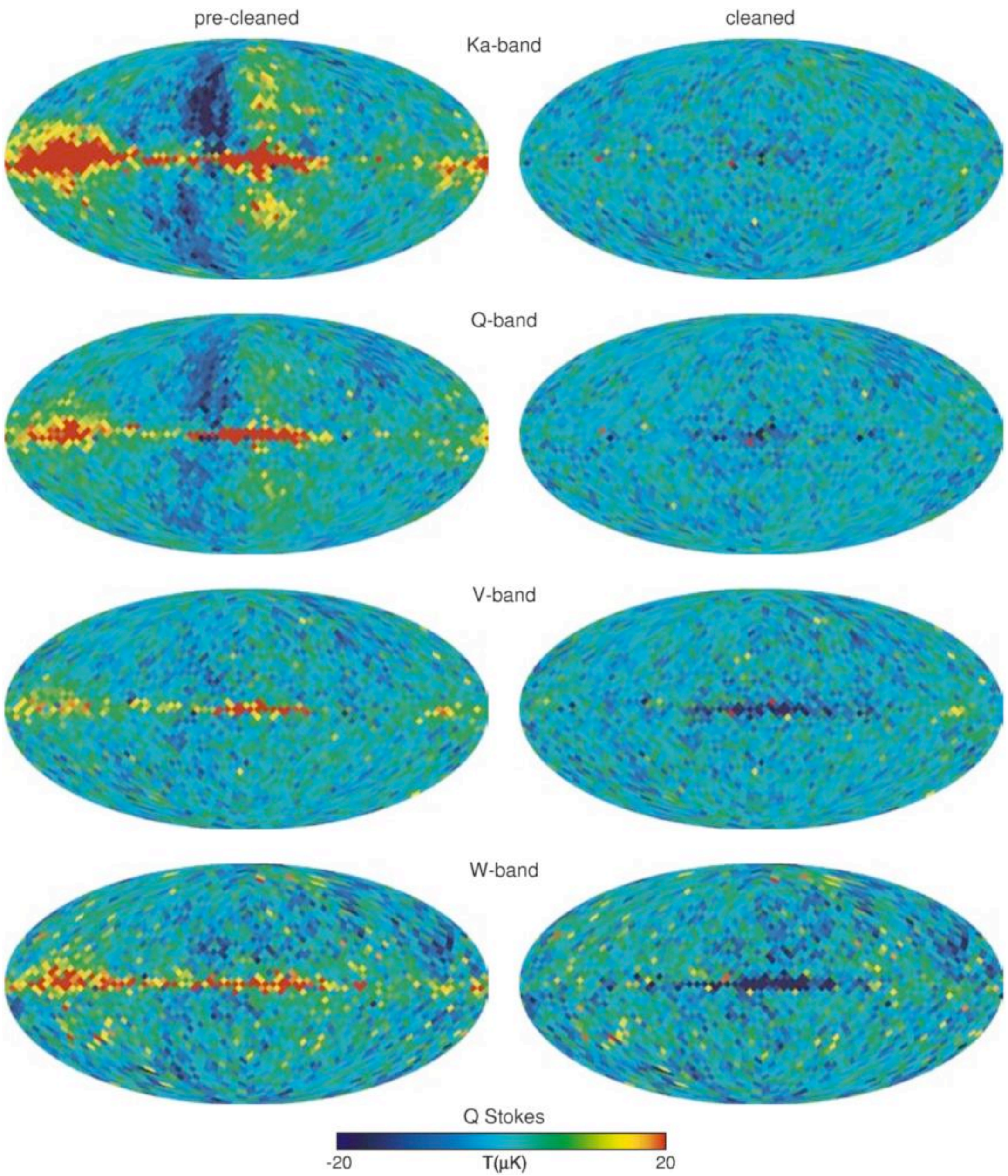
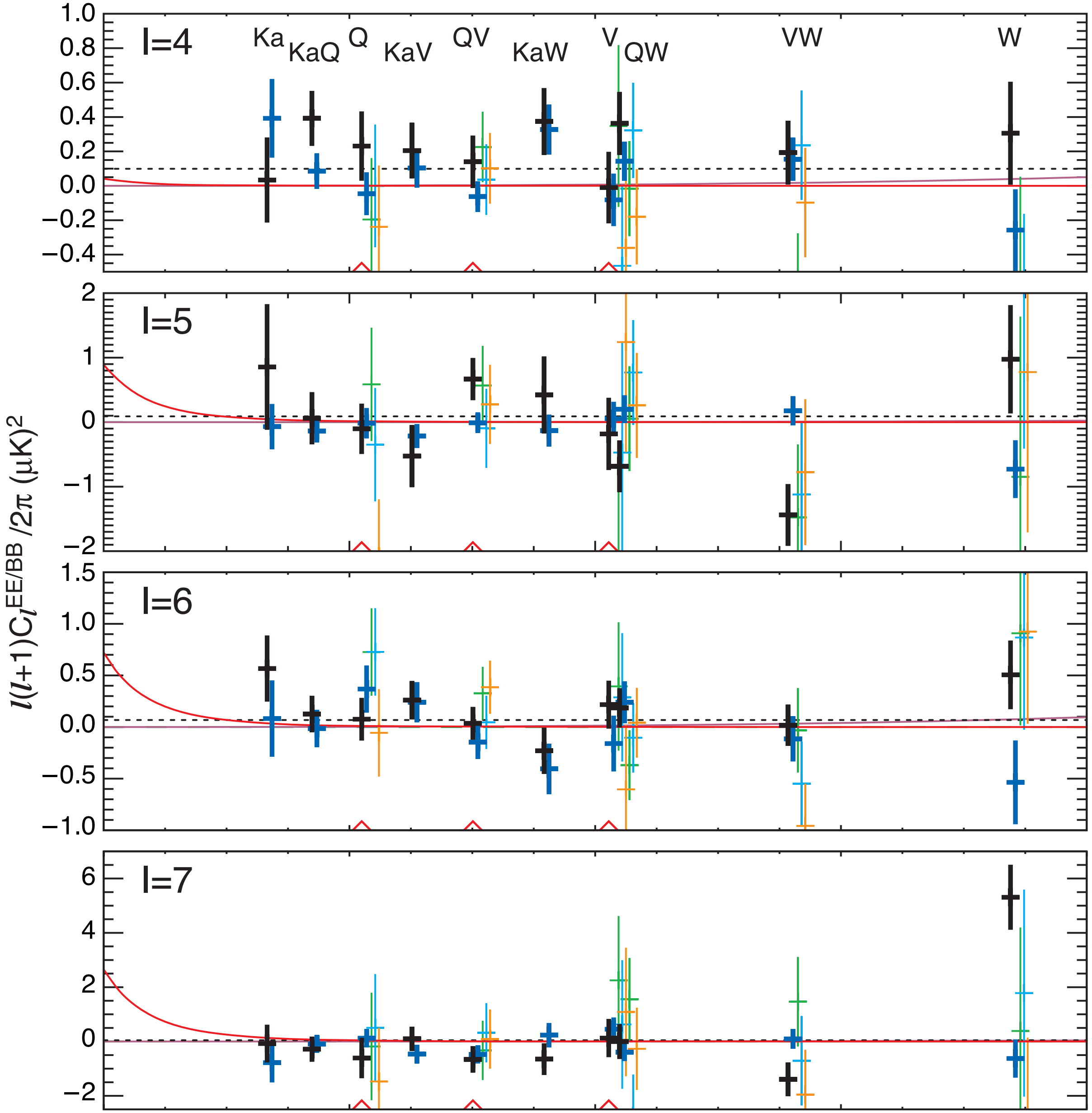


TABLE 4
COMPARISON OF χ^2 BETWEEN PRE-CLEANED AND CLEANED MAPS

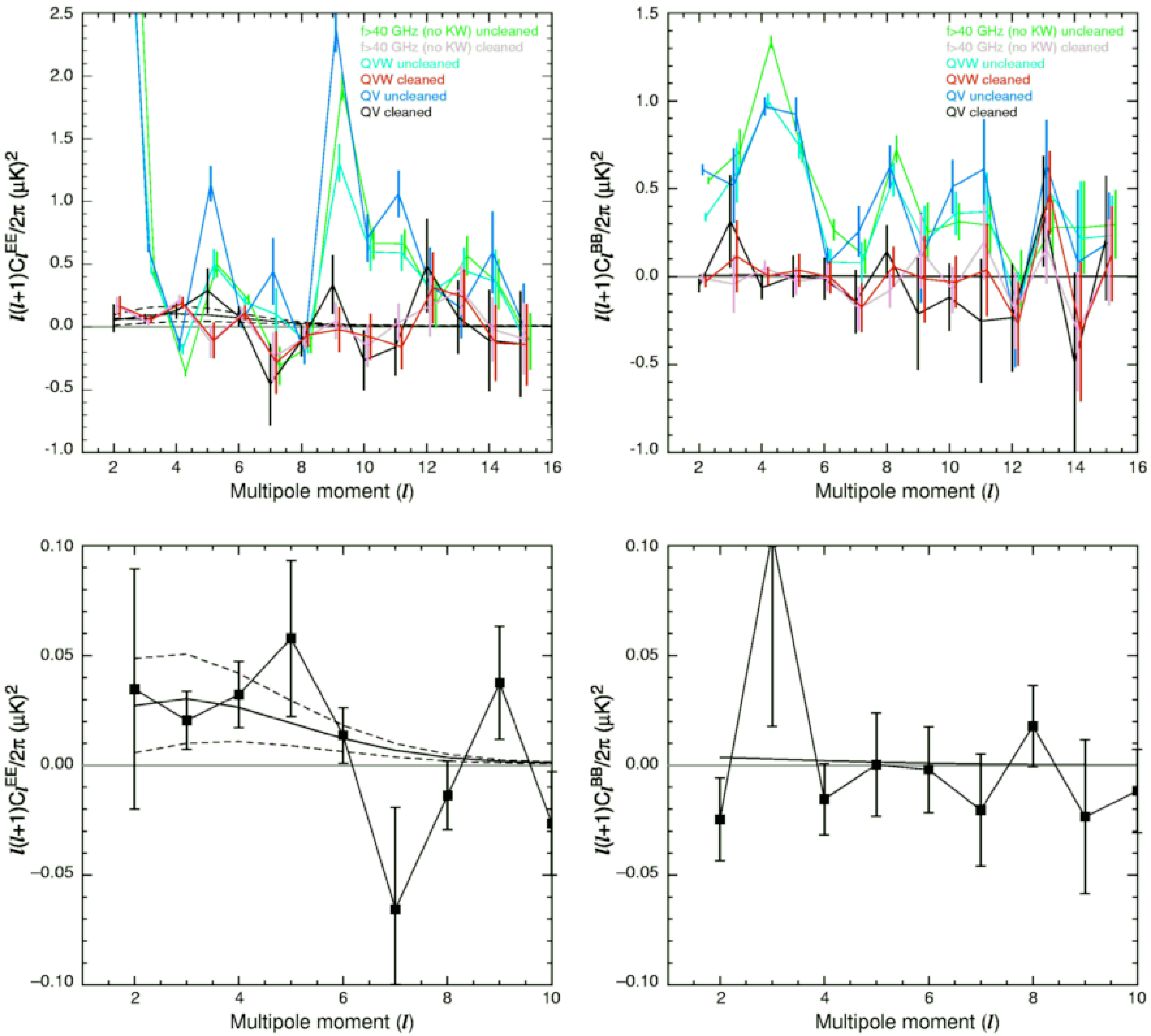
Band	χ^2/ν Pre-cleaned	χ^2/ν Cleaned	ν	$\Delta\chi^2$
Ka	10.65	1.20	6144	58061
Q	3.91	1.09	6144	17326
V	1.36	1.19	6144	1045
W	1.38	1.58	6144	-1229
Ka	2.142	1.096	4534	4743
Q	1.289	1.018	4534	1229
V	1.048	1.016	4534	145
W	1.061	1.050	4534	50

The top half of the table compares χ^2/ν for the full-sky pre-cleaned map to χ^2/ν for full-sky cleaned map. The bottom half makes a similar comparison for the region outside the P06 mask.

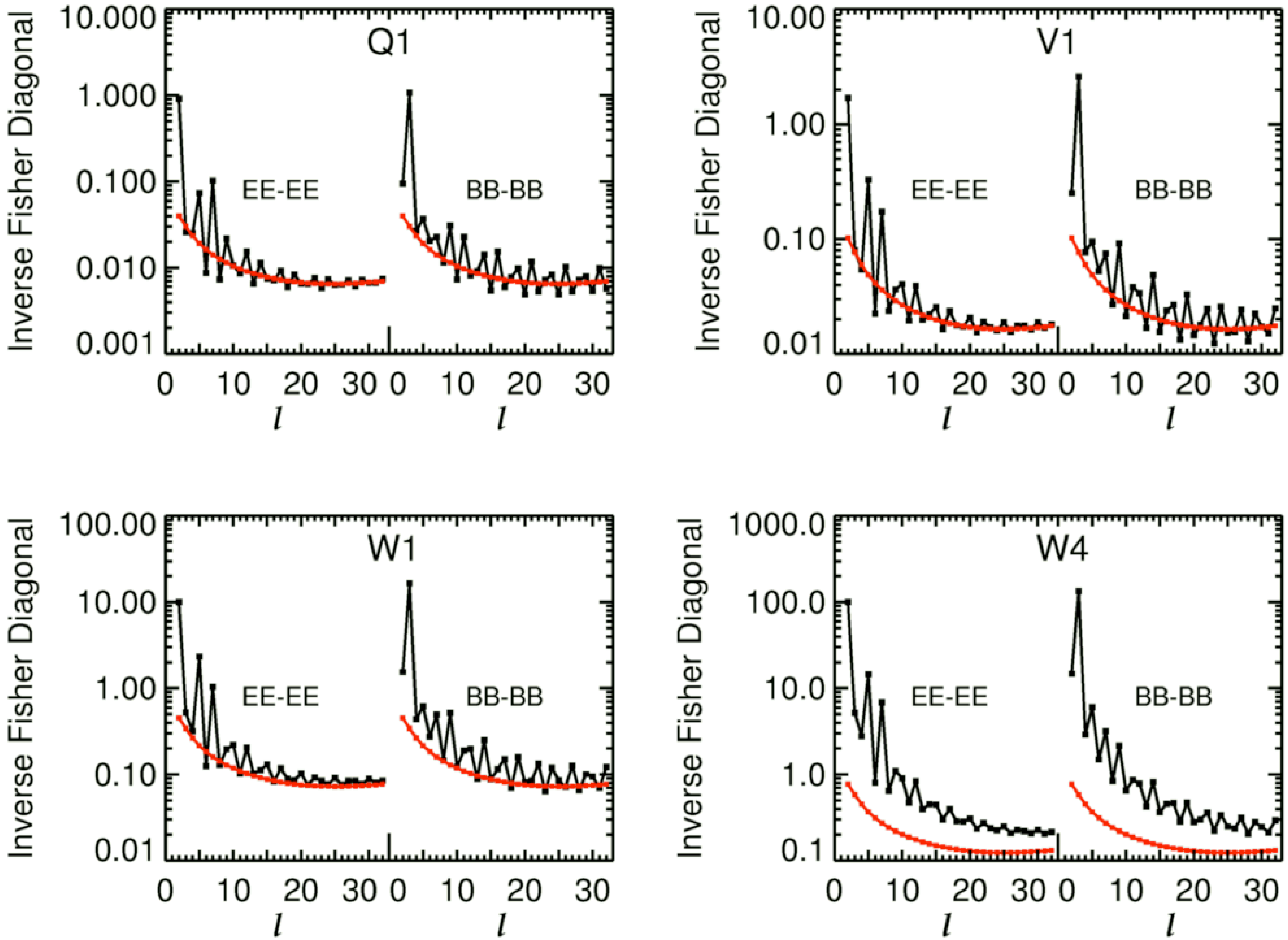
Foreground cleaned C_l(freq)



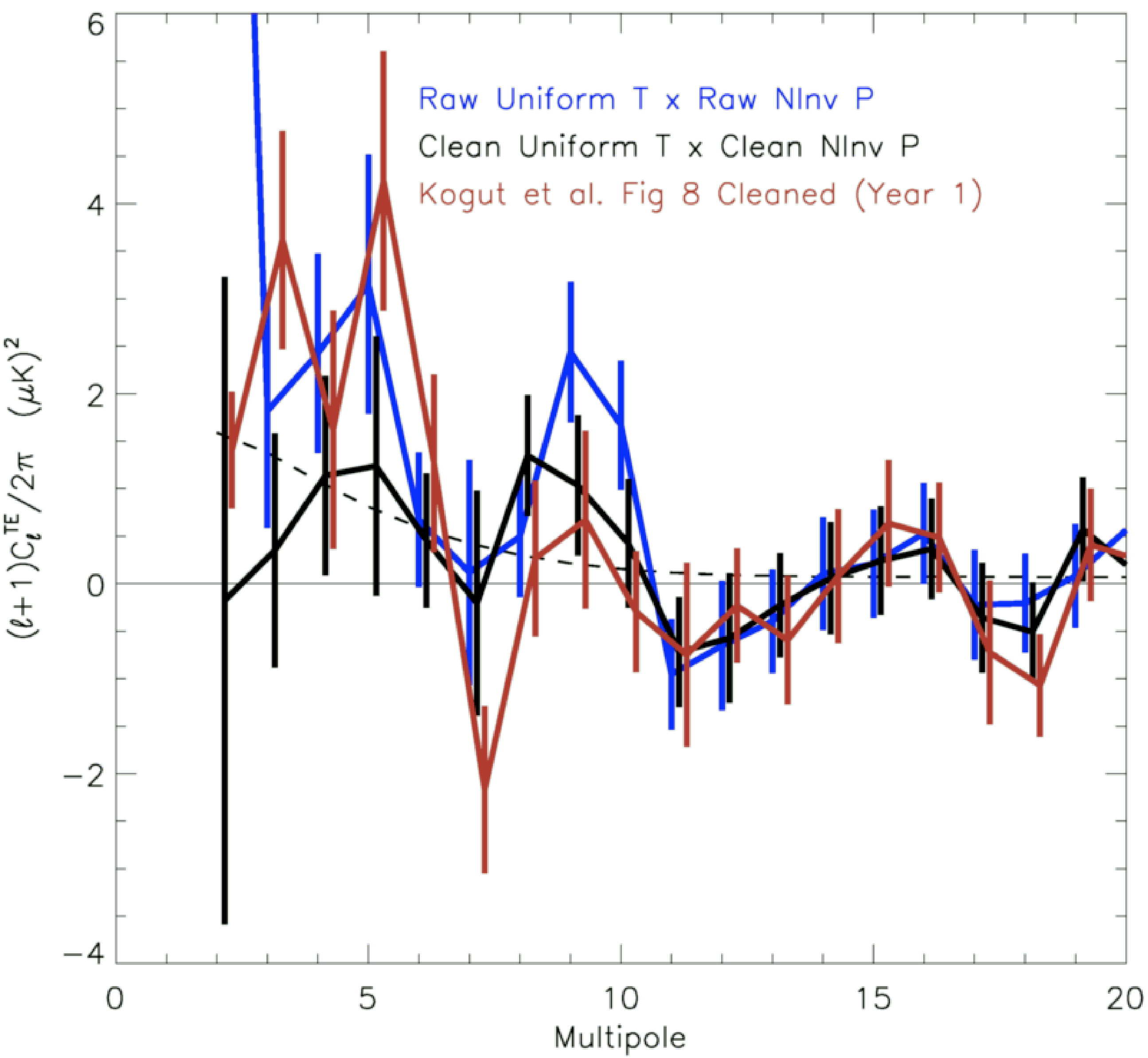
Low-l EE/BB spectra



Large scale noise structure

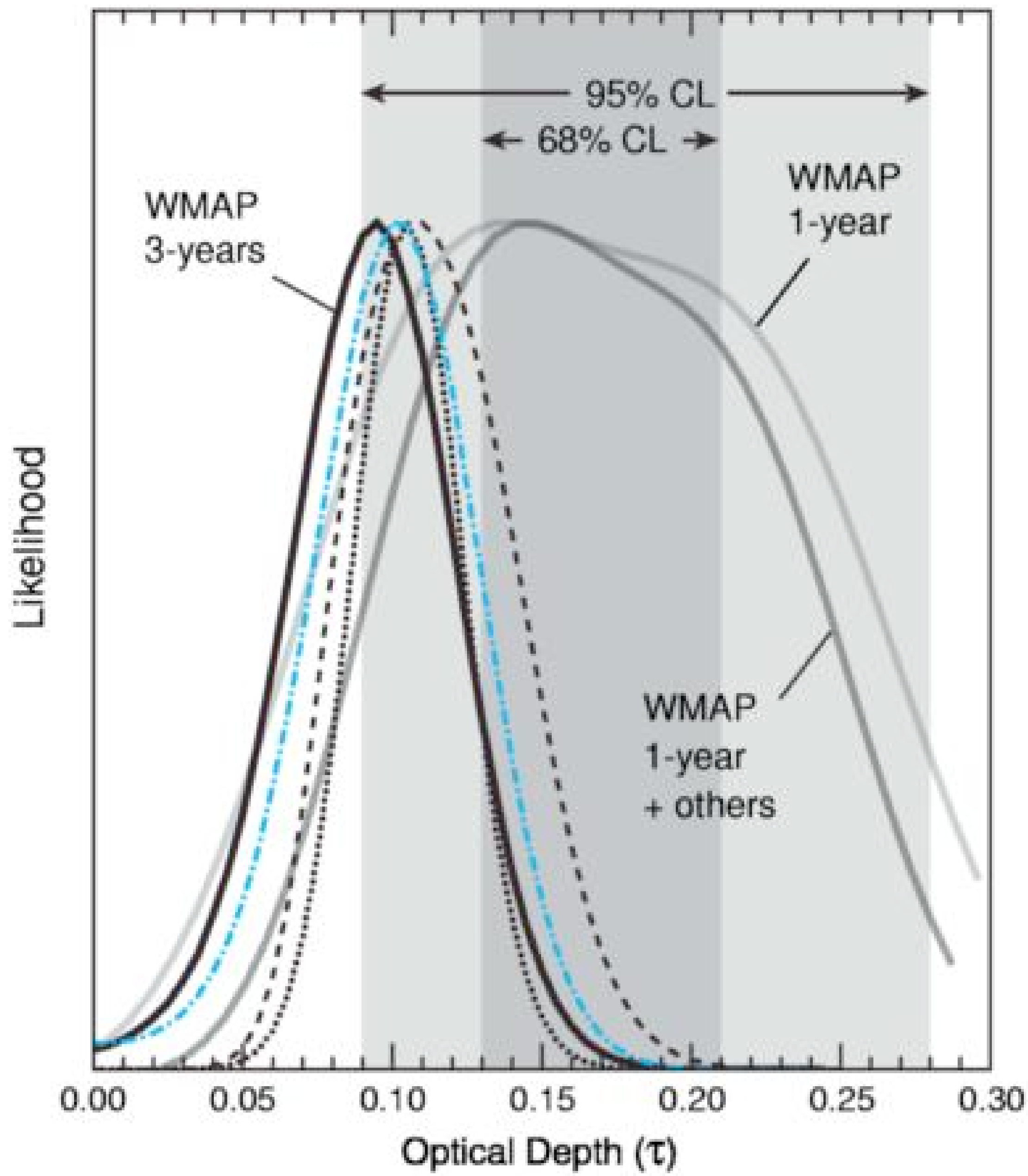


1yr/3yr TE



Raw Uniform T x Raw NInv P
Clean Uniform T x Clean NInv P
Kogut et al. Fig 8 Cleaned (Year 1)
$(\ell+1)C_\ell^{TE}/2\pi \quad (\mu K)^2$
Multipole
6
4
2
0
−2
−4
0
5
10
15
20

1yr/3yr Optical Depth



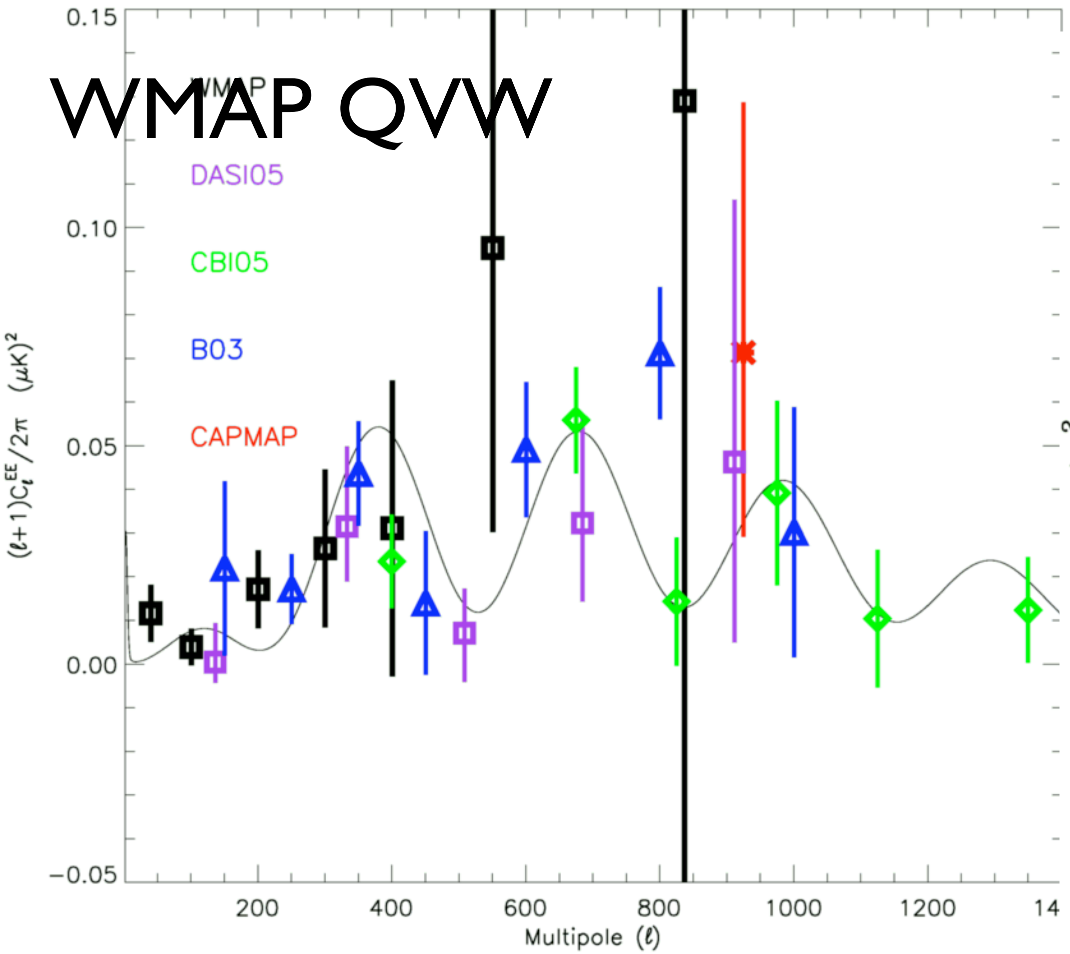
Blame Foregrounds?

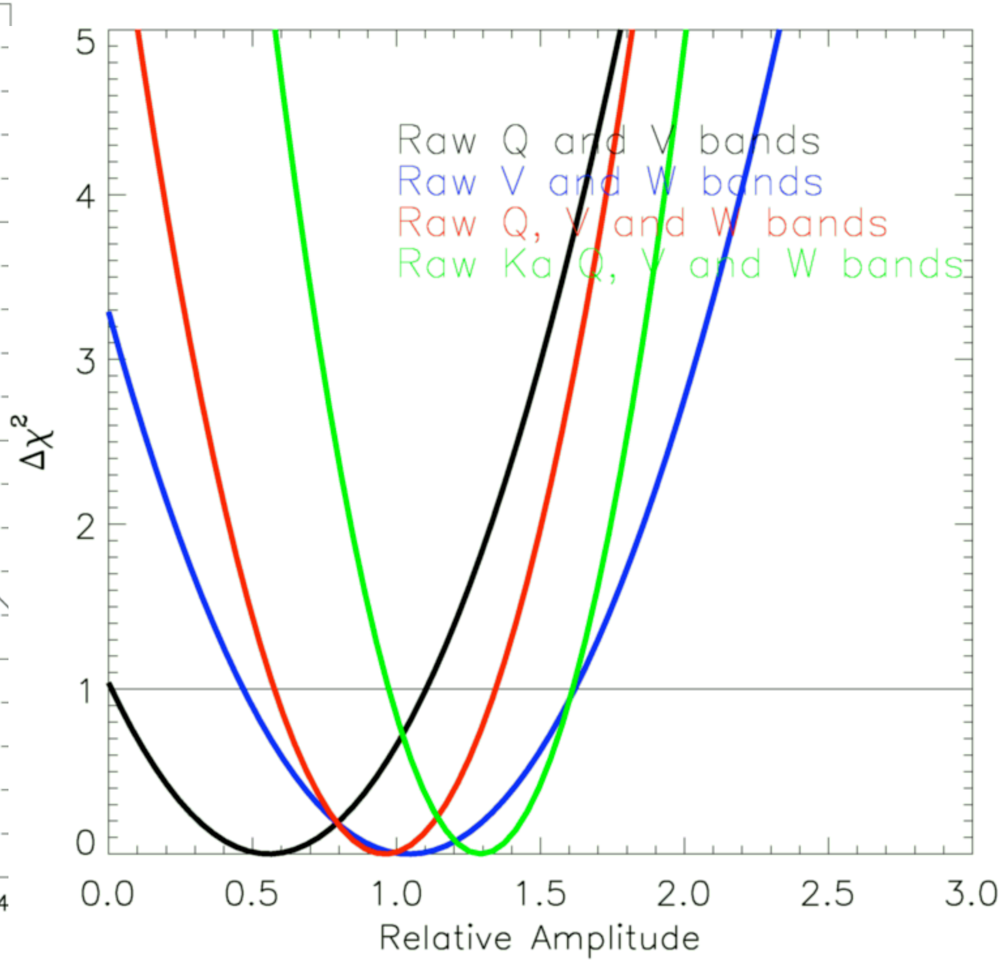
TABLE 9
OPTICAL DEPTH VS. DATA SELECTION

Combination	Exact EE Only	Exact EE & TE	Simple tau EE	Simple tau, no $\ell = 5,7$
KaQV	0.111 ± 0.022	0.111 ± 0.022	...	...
Q	0.100 ± 0.044	0.082 ± 0.043	0.08 ± 0.03	0.085 ± 0.03
QV	0.100 ± 0.029	0.092 ± 0.029	0.110 ± 0.027	$0.085^{+0.045}_{-0.015}$
QV+VV	...	...	0.145 ± 0.03	$0.14^{+0.02}_{-0.06}$
V	0.089 ± 0.048	0.094 ± 0.043	$0.09^{+0.03}_{-0.07}$	$0.10^{+0.03}_{-0.07}$
QVW	0.110 ± 0.021	0.101 ± 0.023	0.090 ± 0.012	0.090 ± 0.015
KaQVW	0.107 ± 0.018	0.106 ± 0.019	0.095 ± 0.015	0.095 ± 0.015

The values of simple tau are computed for $2 \leq \ell \leq 11$. The models are computed in steps of $\Delta\tau = 0.005$ and linearly interpolated. The last column is computed with the errors on $\ell = 5,7$ multiplied by ten. The QV+VV is the QV combination without the QQ component. Since the exact likelihood is based on the Ka, Q, V, and W maps, there is no corresponding entry for QV+VV. Note that the maximum likelihood values are independent of frequency combination indicating that foreground emission is not biasing the determination of τ.

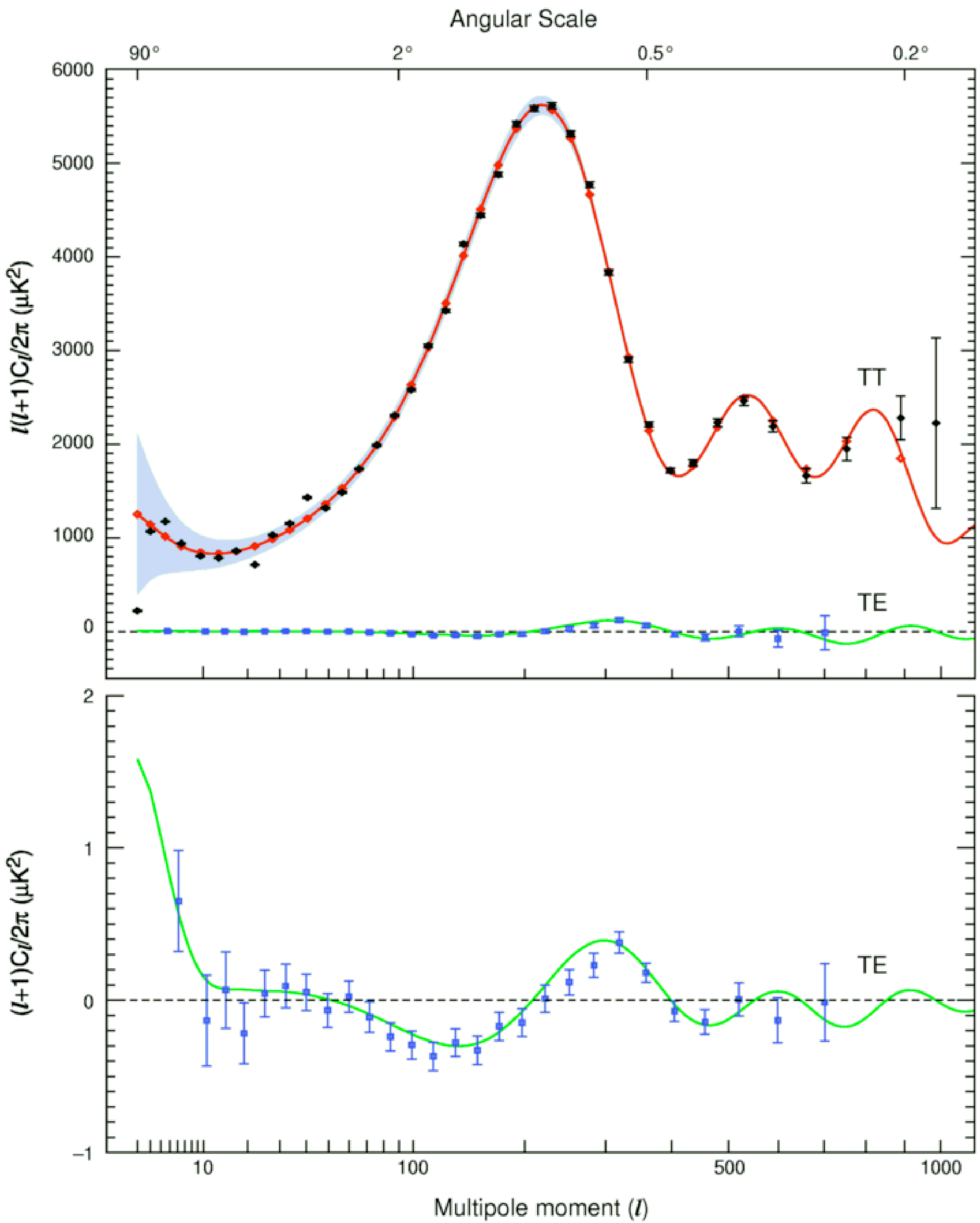
High-l EE

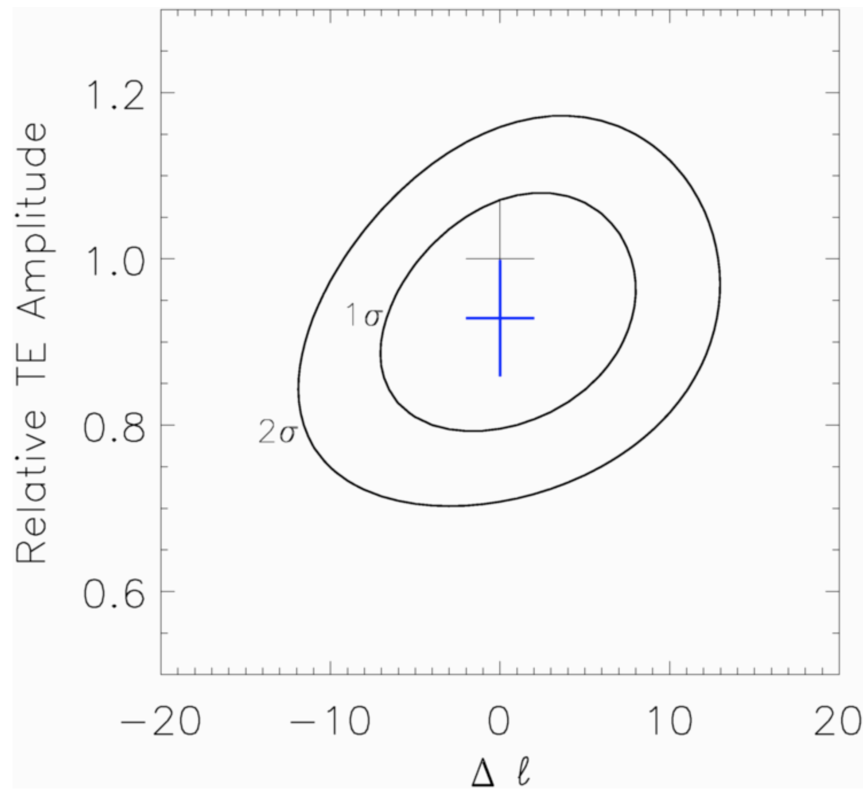




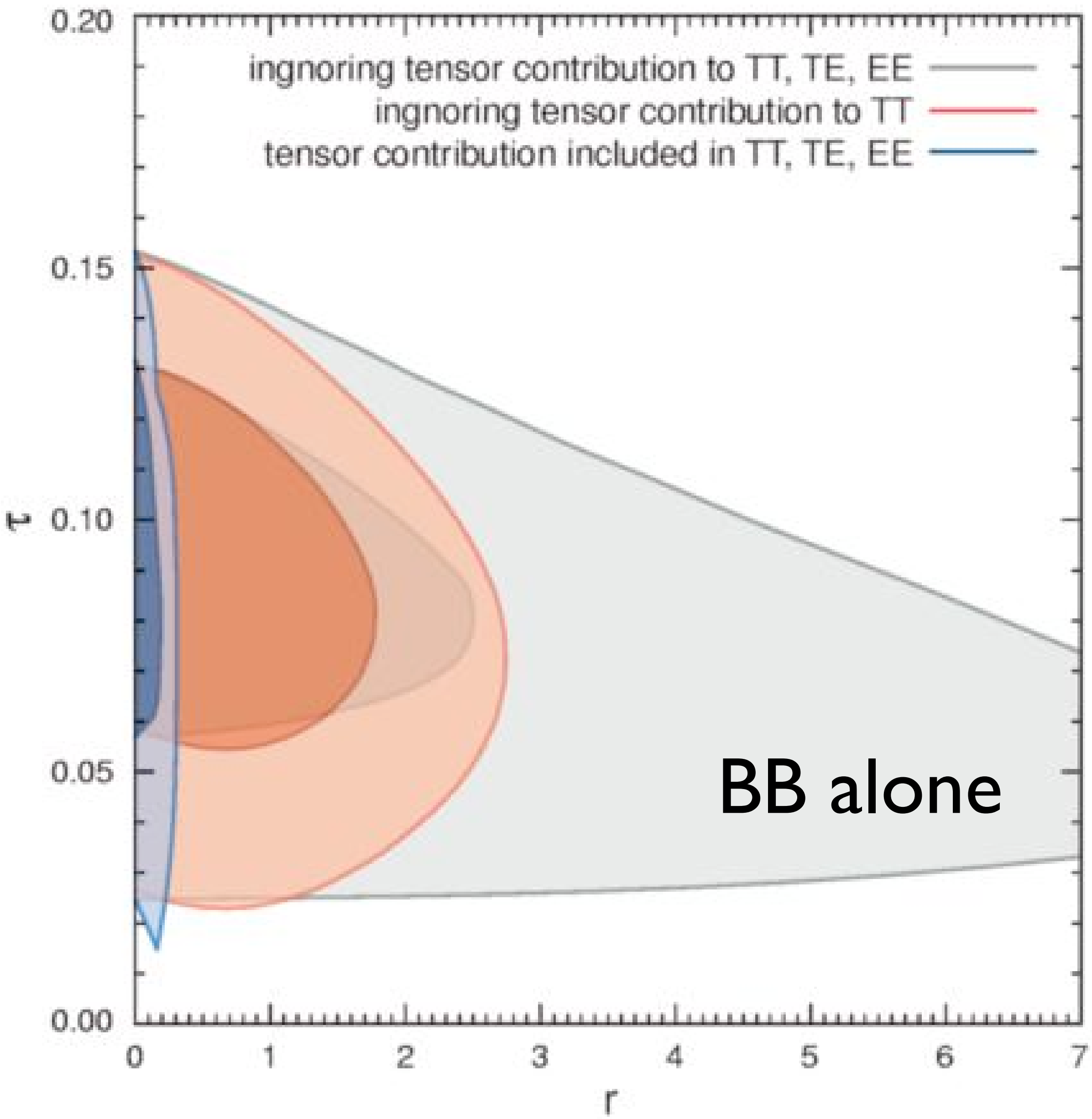
3sigma detection of high-l EE amplitude predicted by TT

High-l TE


Angular Scale
90°
2°
0.5°
0.2°
6000
5000
4000
3000
2000
1000
0
TT
TE
$l(l+1)C_l/2\pi$ (μK^2)
2
1
0
−1
TE
$(l+1)C_l/2\pi$ (μK^2)
10
100
500
1000
Multipole moment (l)


1.2
1.0
0.8
0.6
Relative TE Amplitude
1σ
2σ
−20
−10
0
10
20
Δ ℓ

Who needs BB?



ingnoring tensor contribution to TT, TE, EE
ingnoring tensor contribution to TT
tensor contribution included in TT, TE, EE
0.20
0.15
0.10
0.05
0.00
τ
0
1
2
3
4
5
6
7
r
BB alone

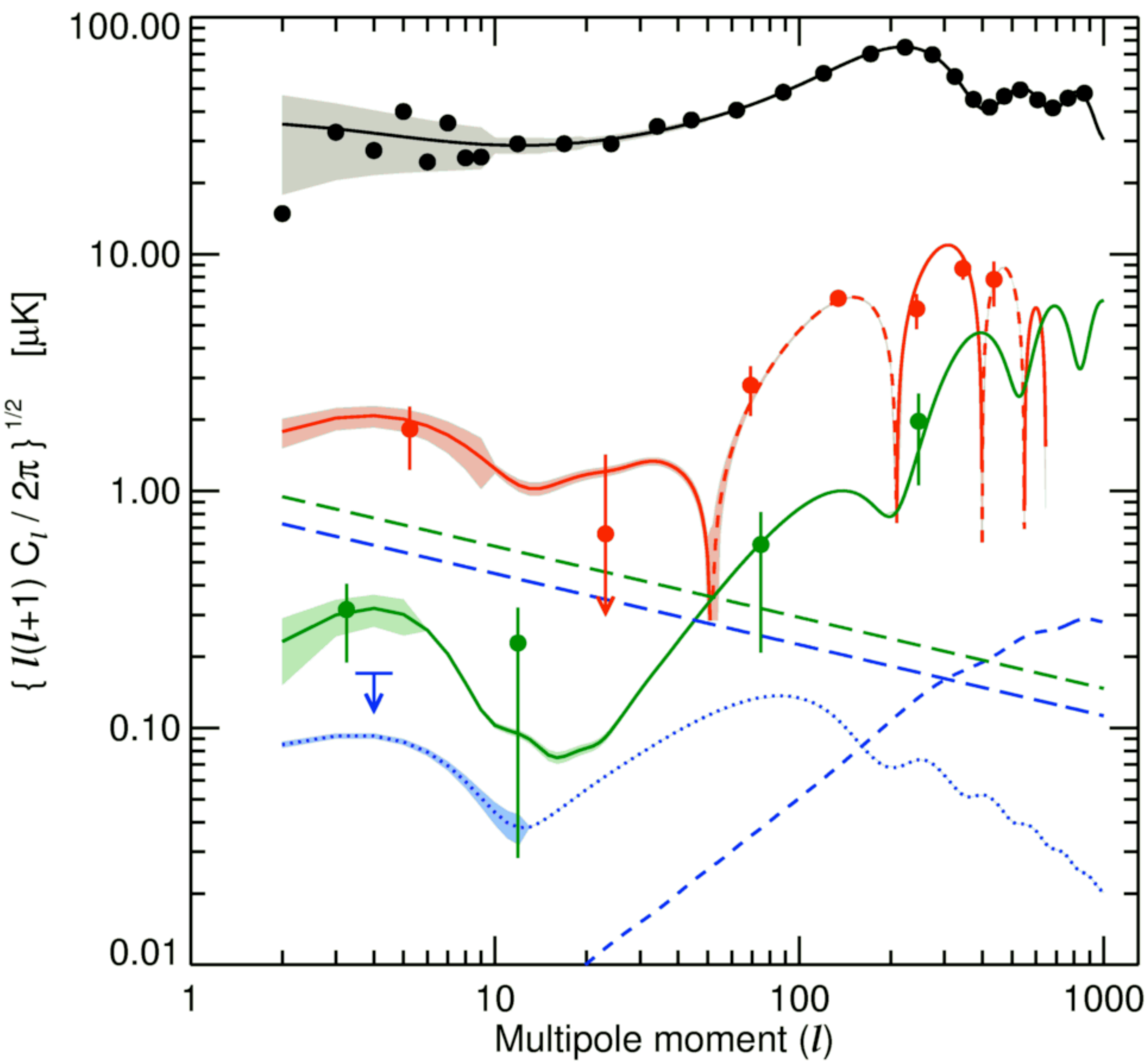
Updated release

- Reduced point source correction amplitude by 18%, increasing the height of the 3rd peak
  - LCDM/WMAP-only Sigma8 increases from 0.74 to 0.77
- Extended low-l exact TT likelihood from lmax=12 to lmax=30
- Likelihood code available on LAMBDA

Future prospects

- “Future CMB observations that can provide an accurate measurement of the optical depth or third acoustic peak are needed to constrain parameters significantly better with CMB alone.” (Lewis astro-ph/0603753)
- WMAP funded for 8 years of observations

FIN


100.00
10.00
1.00
0.10
0.01
1
10
100
1000
Multipole moment (l)
$\{ l(l+1)\, C_l / 2\pi \}^{1/2}$ [μK]