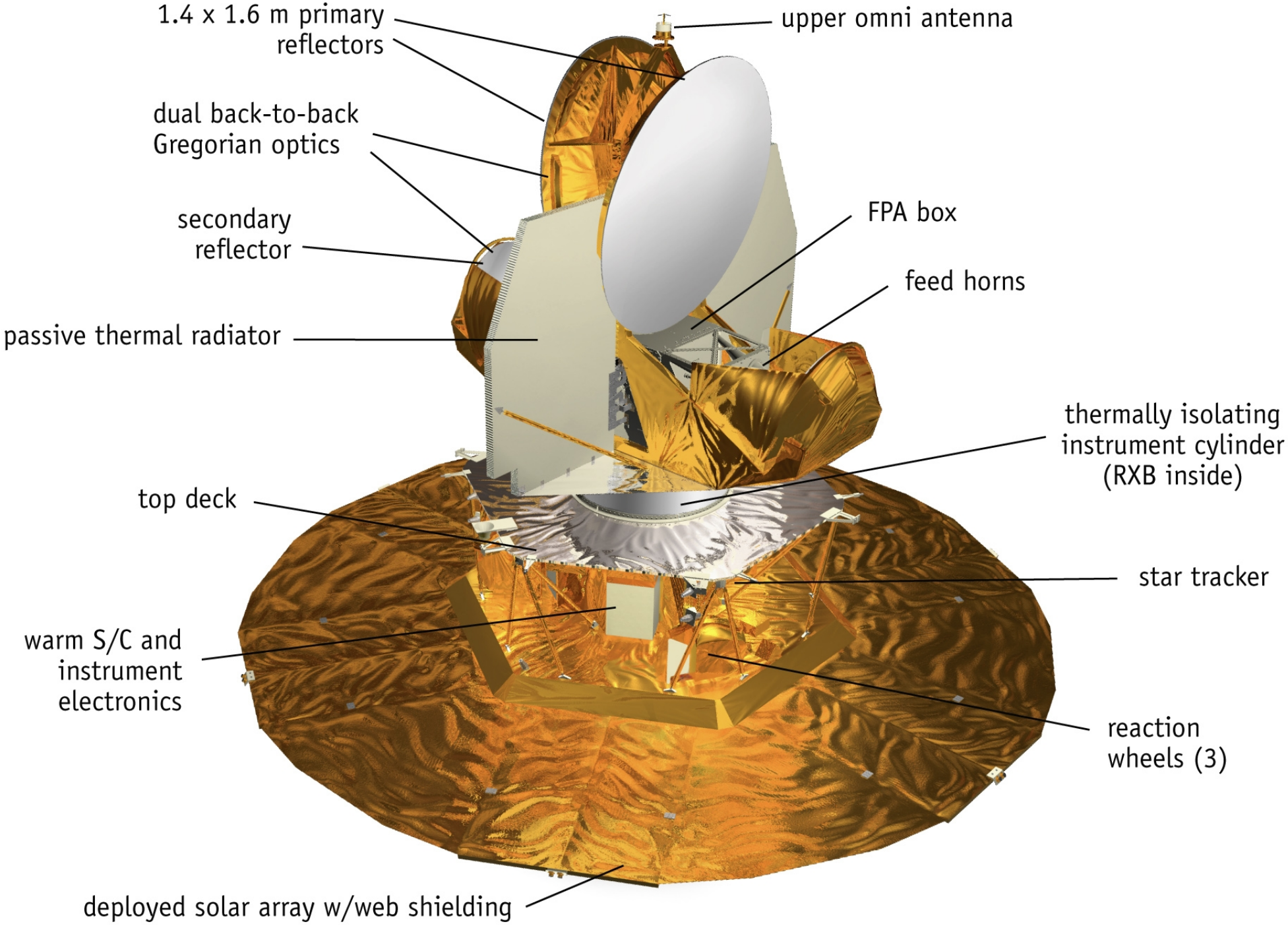
First Year WMAP Results

(FIRST-YEAR WILKINSON MICROWAVE ANISOTROPY PROBE (WMAP) OBSERVATIONS: PRELIMINARY MAPS AND BASIC RESULTS

Bennett et al, 2003)

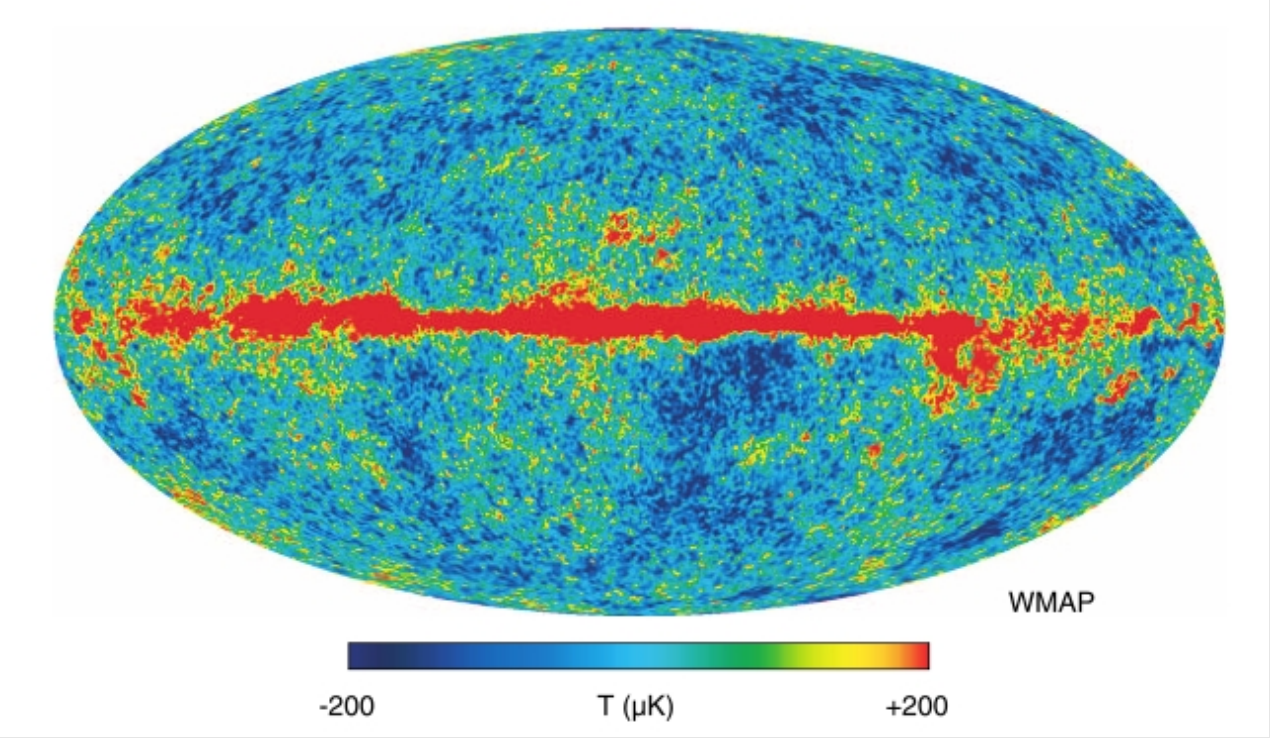

1.4 x 1.6 m primary reflectors
upper omni antenna
dual back-to-back Gregorian optics
secondary reflector
FPA box
feed horns
passive thermal radiator
thermally isolating instrument cylinder (RXB inside)
top deck
star tracker
warm S/C and instrument electronics
reaction wheels (3)
deployed solar array w/web shielding

Overview

- Observations
- Foreground
- Spectrum
- Cosmology
- Polarization

Observations

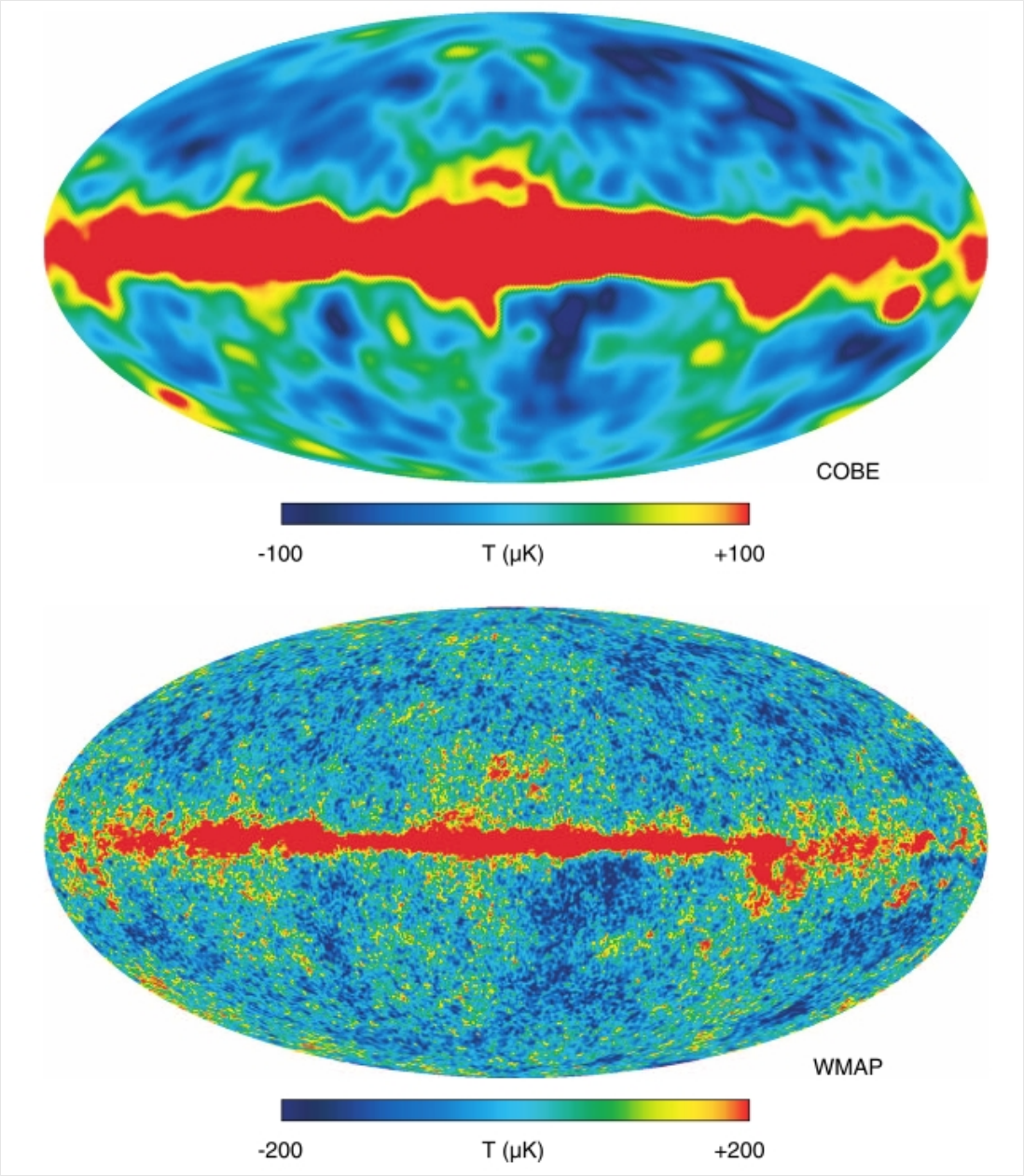
- Observe in 5 bands: **K**,**Ka**,**Q**,**V**,**W** (23 to 94 GHz)
- Two feed horns used to measure differences
- Temp difference measurements made into map



Observations

COBE

WMAP



Foreground

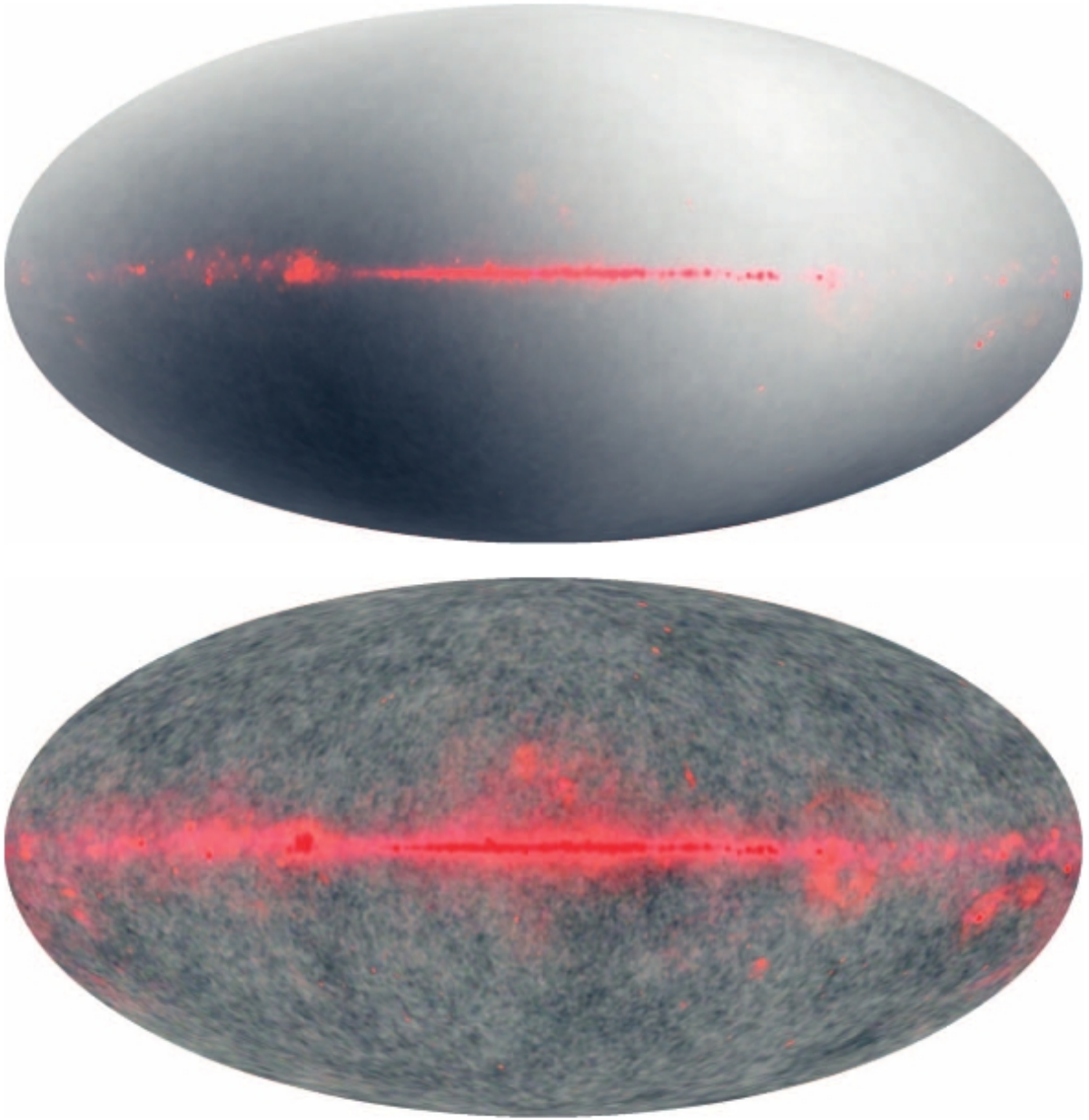


FIG. 10.—False-color images representing the spectral information from multiple *WMAP* bands. Q band is red, V band is green, and W band is blue. A CMB thermodynamic spectrum is gray. *Top*: Three-color combination image from the Q, V, and W-band maps. The dipole and high Galactic latitude anisotropy are seen. *Bottom*: Similar false-color image but with the dipole subtracted.

Foreground

- Galactic contamination strongest in K band
- Could use a linear combination of bands to minimize galactic emission
- Or fit model of dust emission and account for it

- Produces complicated errors

Foreground

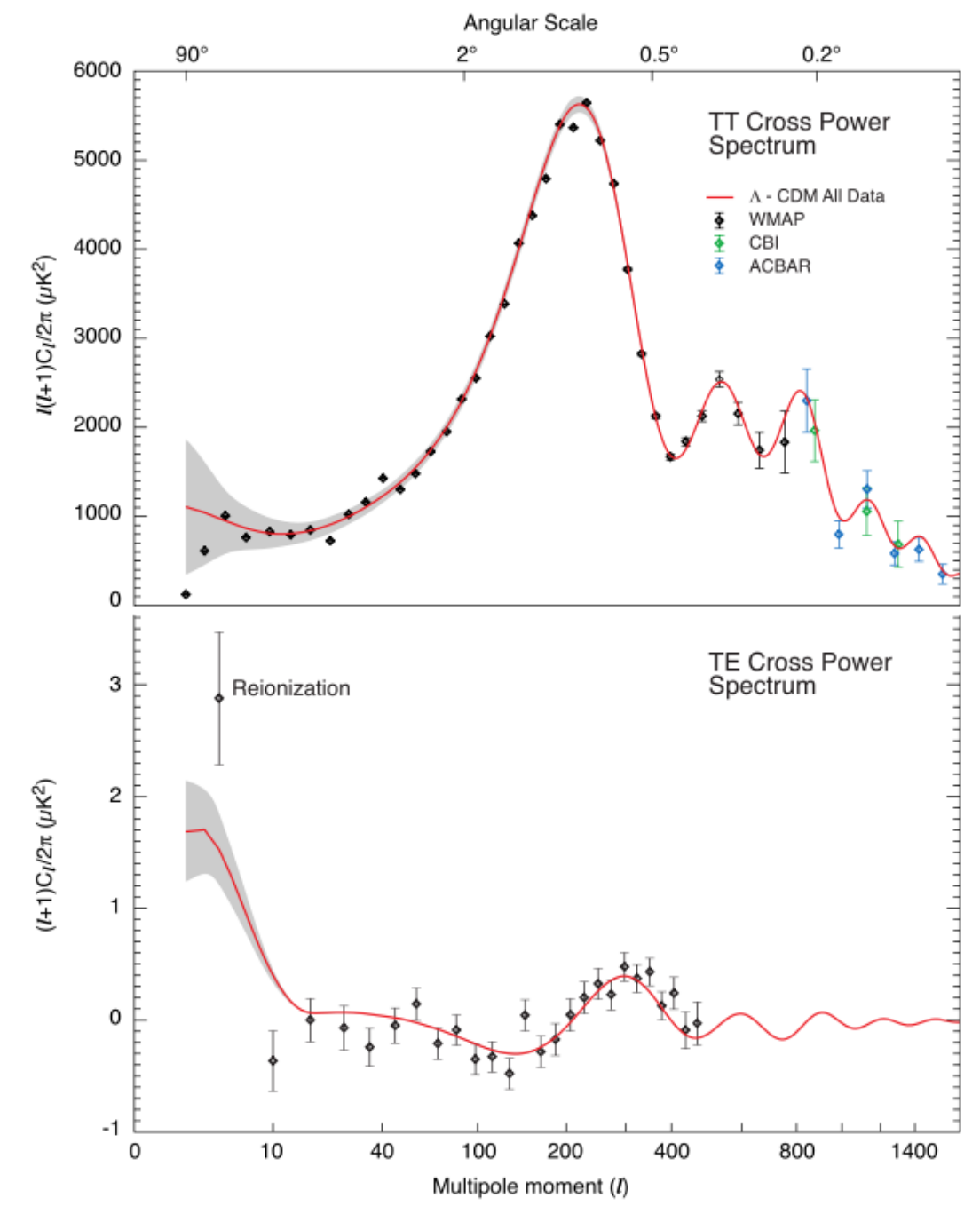
- Solution: Mask out 'bad' areas
- Use dust emission map as mask
- Include ~700 point sources

- S-Z Effect?

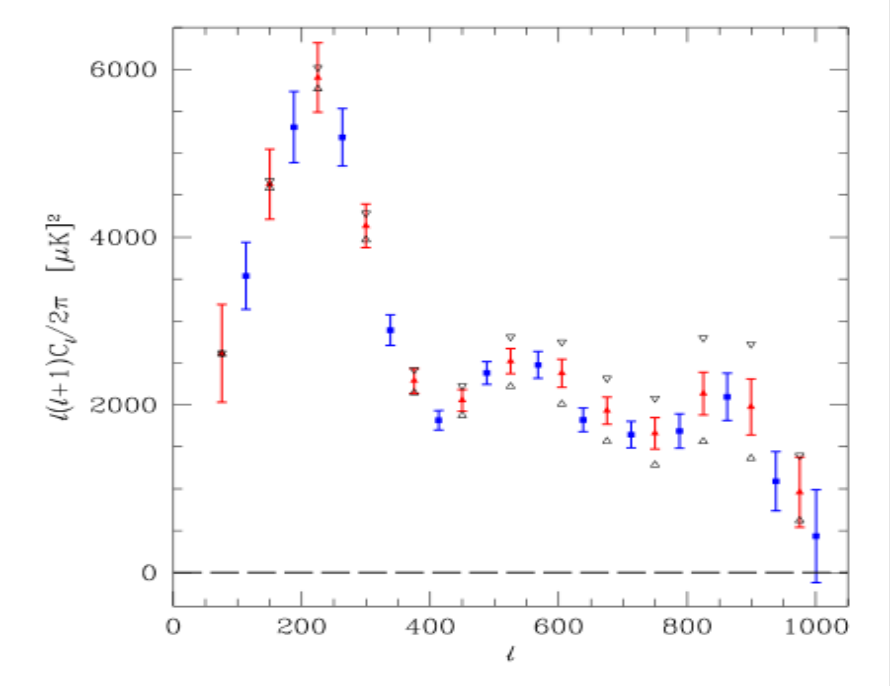
Spectrum

- Use spherical harmonic transform
  - Masks make errors correlated
- Di- and quadrupole moments found to be consistent with COBE

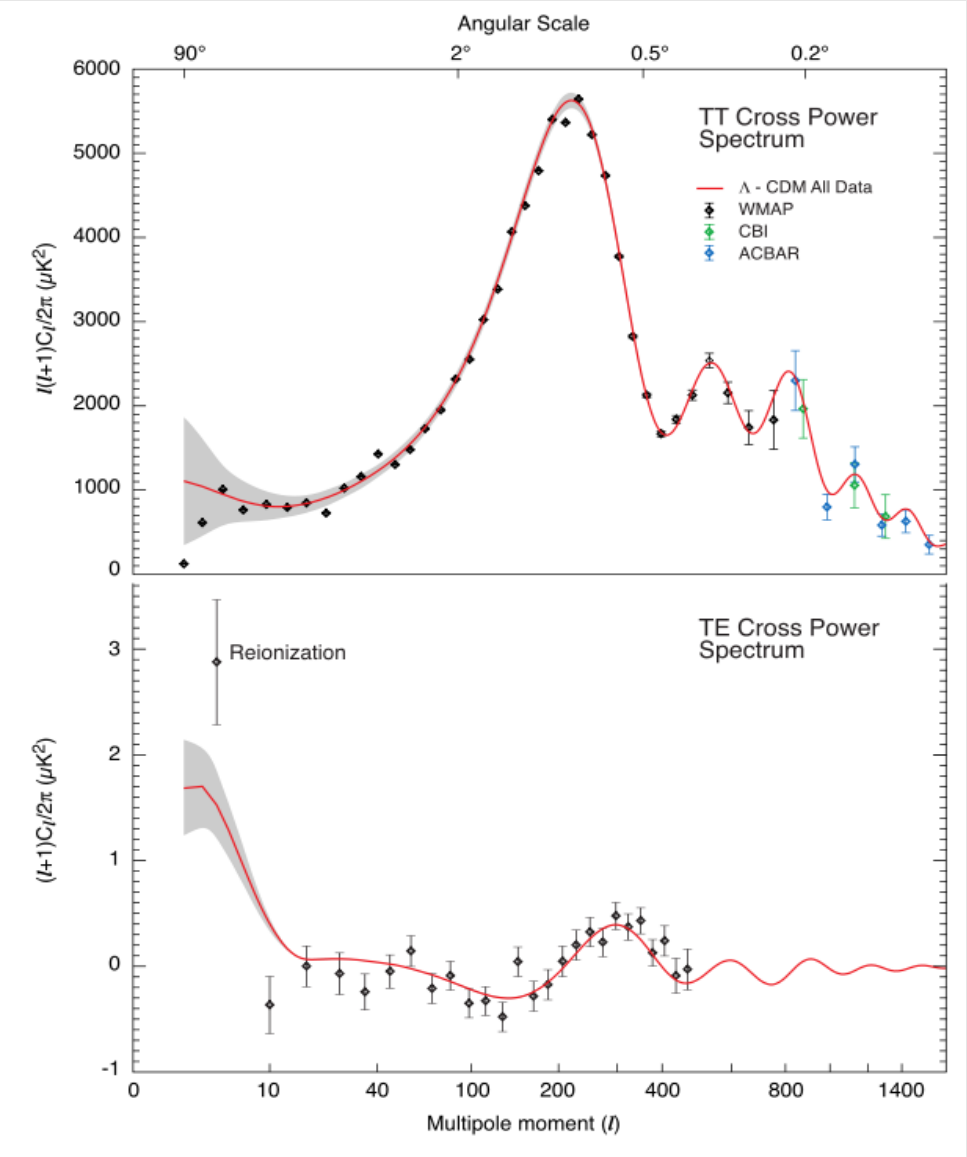
Spectrum


Angular Scale
90°
2°
0.5°
0.2°
TT Cross Power Spectrum
Λ - CDM All Data
WMAP
CBI
ACBAR
l(l+1)C_l/2π (μK^2)
6000
5000
4000
3000
2000
1000
0
TE Cross Power Spectrum
Reionization
(l+1)C_l/2π (μK^2)
3
2
1
0
-1
0
10
40
100
200
400
800
1400
Multipole moment (l)

Observations



BOOMERANG



Cosmology

TABLE 3

"BEST" COSMOLOGICAL PARAMETERS

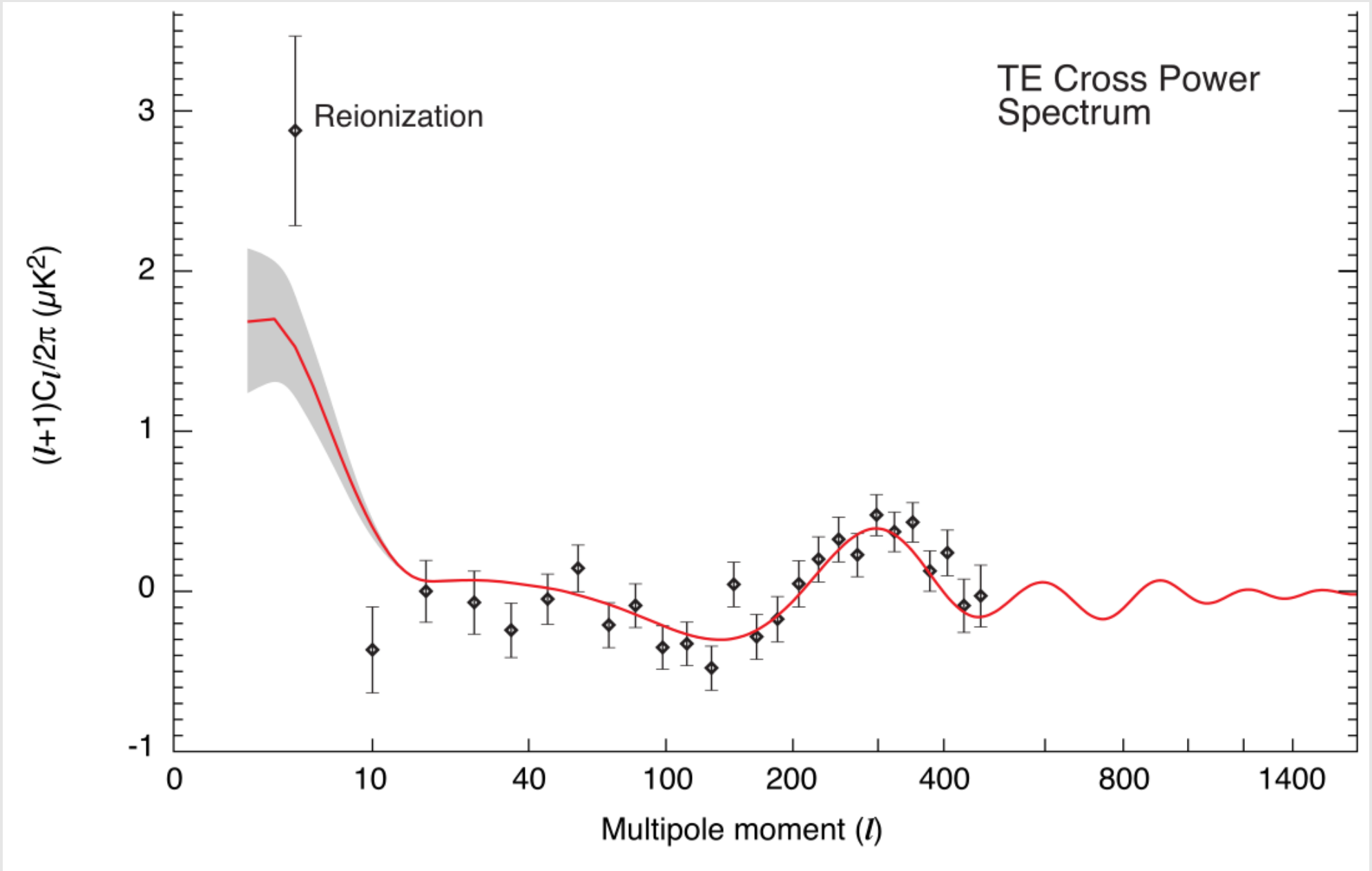
Description	Symbol	Value	+ Uncertainty	− Uncertainty
Total density	$\Omega_{\rm tot}$	1.02	0.02	0.02
Equation of state of quintessence	w	<-0.78	95% CL	...
Dark energy density	Ω_Λ	0.73	0.04	0.04
Baryon density	$\Omega_b h^2$	0.0224	0.0009	0.0009
Baryon density	Ω_b	0.044	0.004	0.004
Baryon density ($\rm cm^{-3}$)	n_b	2.5×10^{-7}	0.1×10^{-7}	0.1×10^{-7}
Matter density	$\Omega_m h^2$	0.135	0.008	0.009
Matter density	Ω_m	0.27	0.04	0.04
Light neutrino density	$\Omega_\nu h^2$	<0.0076	95% CL	...
CMB temperature (K)[a]	$T_{\rm CMB}$	2.725	0.002	0.002
CMB photon density ($\rm cm^{-3}$)[b]	n_γ	410.4	0.9	0.9
Baryon-to-photon ratio	η	6.1×10^{-10}	0.3×10^{-10}	0.2×10^{-10}
Baryon-to-matter ratio	$\Omega_b \Omega_m^{-1}$	0.17	0.01	0.01
Fluctuation amplitude in $8\,h^{-1}$ Mpc spheres	σ_8	0.84	0.04	0.04
Low-z cluster abundance scaling	$\sigma_8 \Omega_m^{0.5}$	0.44	0.04	0.05
Power spectrum normalization (at $k_0 = 0.05\ \rm Mpc^{-1}$)[c]	A	0.833	0.086	0.083
Scalar spectral index (at $k_0 = 0.05\ \rm Mpc^{-1}$)[c]	n_s	0.93	0.03	0.03
Running index slope (at $k_0 = 0.05\ \rm Mpc^{-1}$)[c]	$dn_s/d\ln k$	-0.031	0.016	0.018
Tensor-to-scalar ratio (at $k_0 = 0.002\ \rm Mpc^{-1}$)	r	<0.90	95% CL	...
Redshift of decoupling	$z_{\rm dec}$	1089	1	1
Thickness of decoupling (FWHM)	$\Delta z_{\rm dec}$	195	2	2
Hubble constant	h	0.71	0.04	0.03
Age of universe (Gyr)	t_0	13.7	0.2	0.2
Age at decoupling (kyr)	$t_{\rm dec}$	379	8	7
Age at reionization (Myr, 95% CL)	t_r	180	220	80
Decoupling time interval (kyr)	$\Delta t_{\rm dec}$	118	3	2
Redshift of matter-energy equality	$z_{\rm eq}$	3233	194	210
Reionization optical depth	τ	0.17	0.04	0.04
Redshift of reionization (95% CL)	z_r	20	10	9
Sound horizon at decoupling (deg)	θ_A	0.598	0.002	0.002
Angular size distance (Gpc)	d_A	14.0	0.2	0.3
Acoustic scale[d]	ℓ_A	301	1	1
Sound horizon at decoupling (Mpc)[d]	r_s	147	2	2

Cosmology

- Fits for various parameters

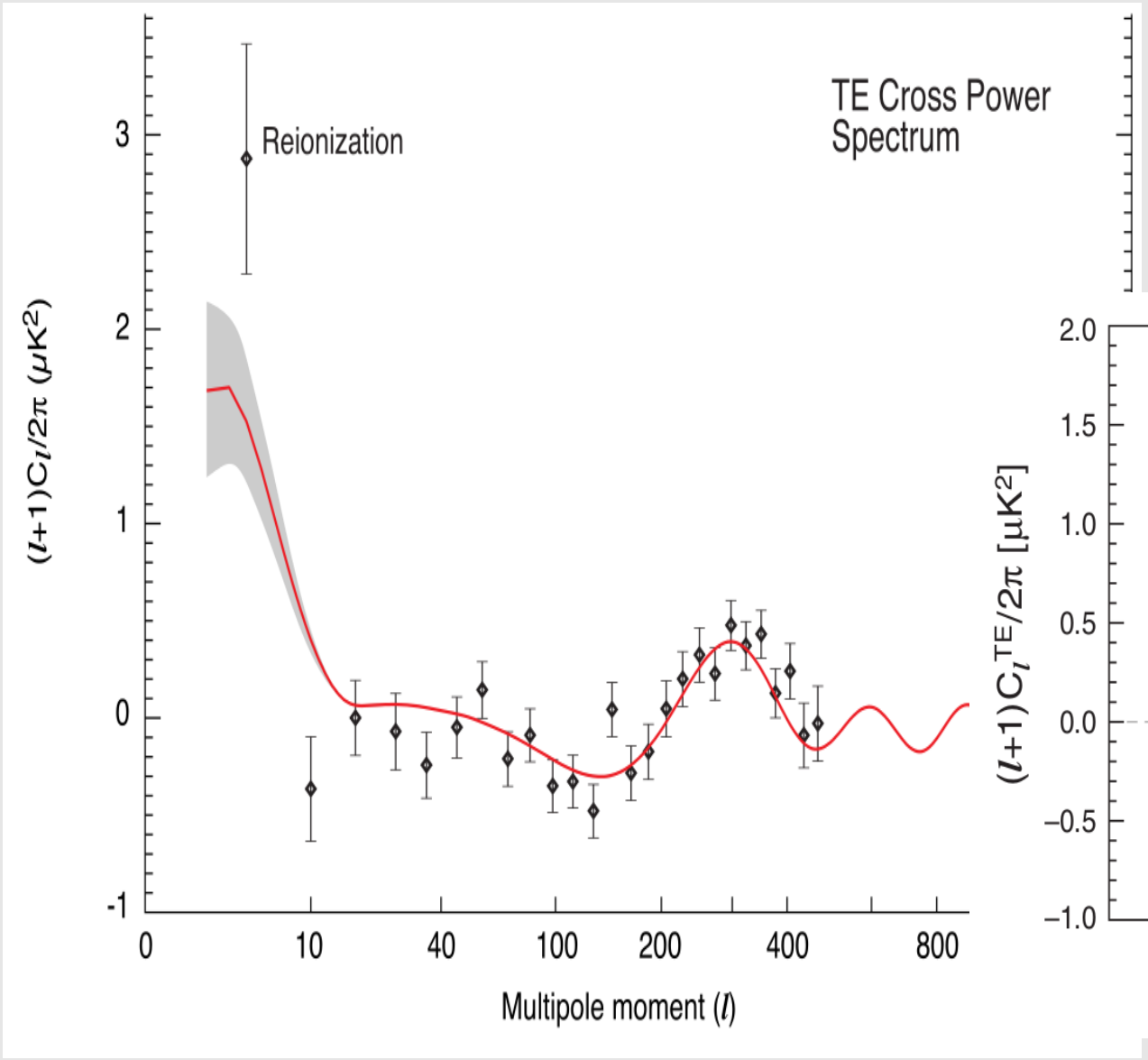
	BOOMERANG	**WMAP 1-year**	WMAP 7-year
$100\Omega_b h^2$	3.0 ± 0.4	**2.24 ± 0.09**	2.249 ± 0.057
Ω_Λ	0.37 ± 0.23	**0.73 ± 0.04**	0.727 ± 0.030
t_0(Gyr)	11.9 ± 1.6	**13.7 ± 0.2**	13.77 ± 0.13
z_r		**20 ± 10**	10.6 ± 1.2

Polarization

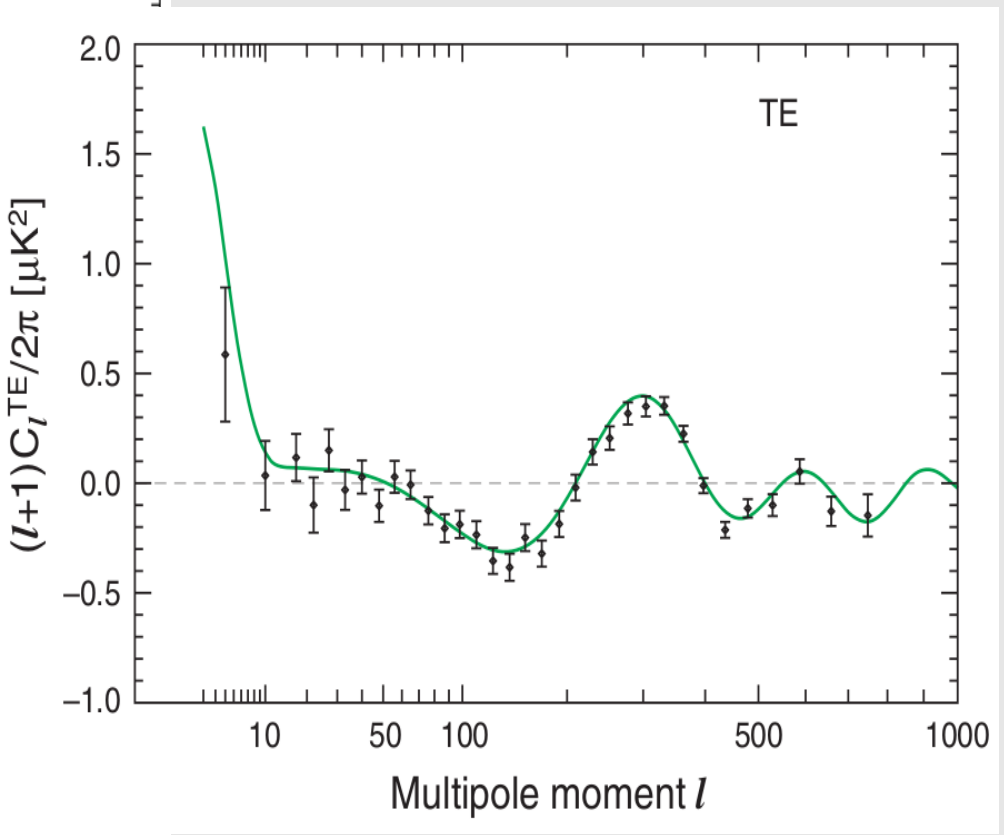


Polarization

WMAP 1st year



WMAP 7th year



Polarization