CMB Slides

Penzias & Wilson

- stumbled into CMB in 1965 while studying galaxy
- found excess ~3 K thermal radiation in all directions (~1 mm wavelength)
- only later realized what it was
- Nobel Prize 1978

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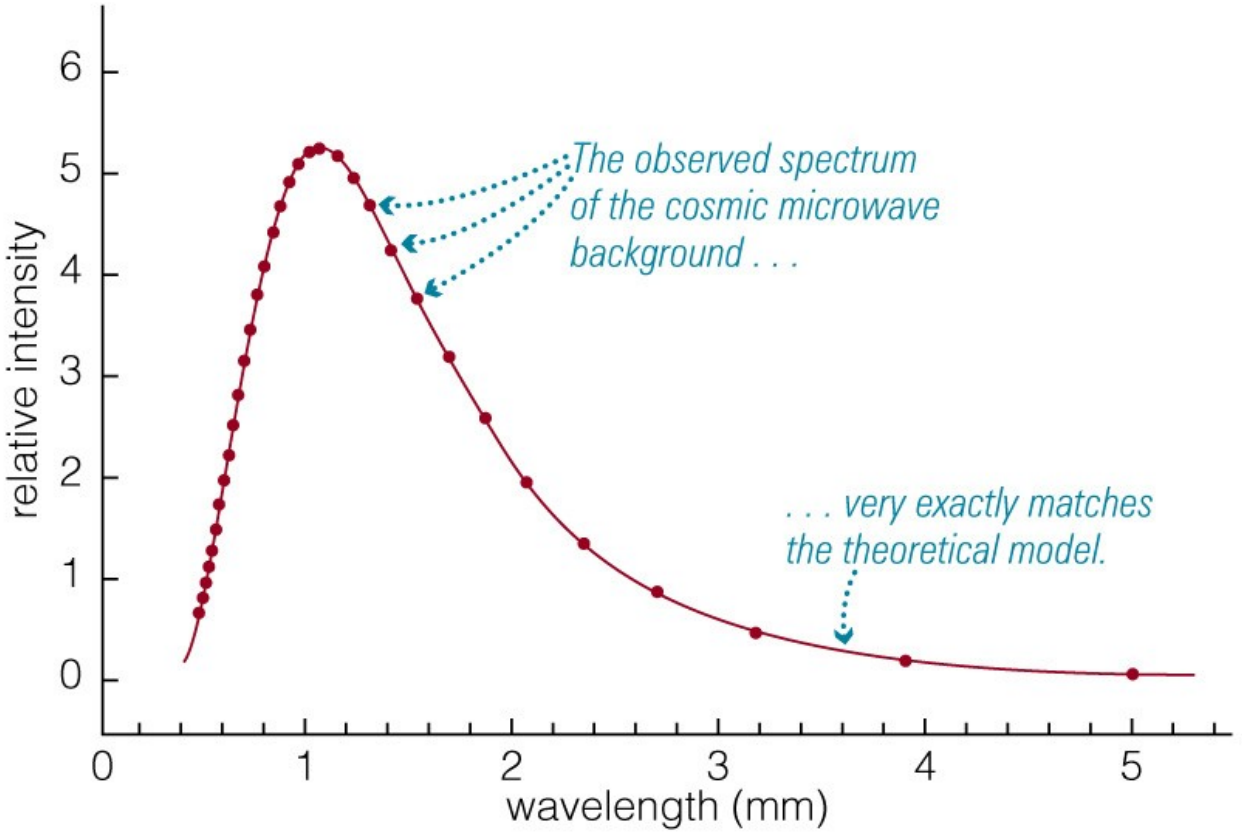
CMB Spectrum

Most Perfect Thermal Emitter Ever Measured!



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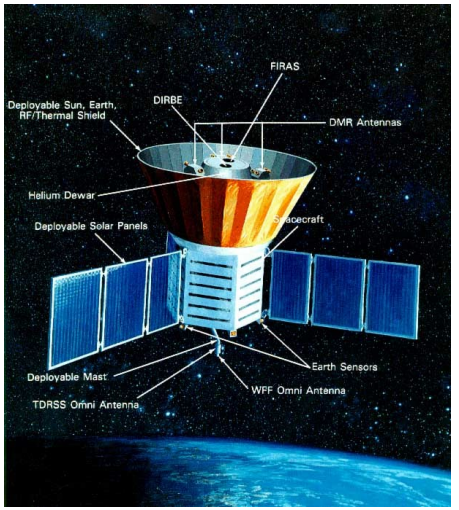


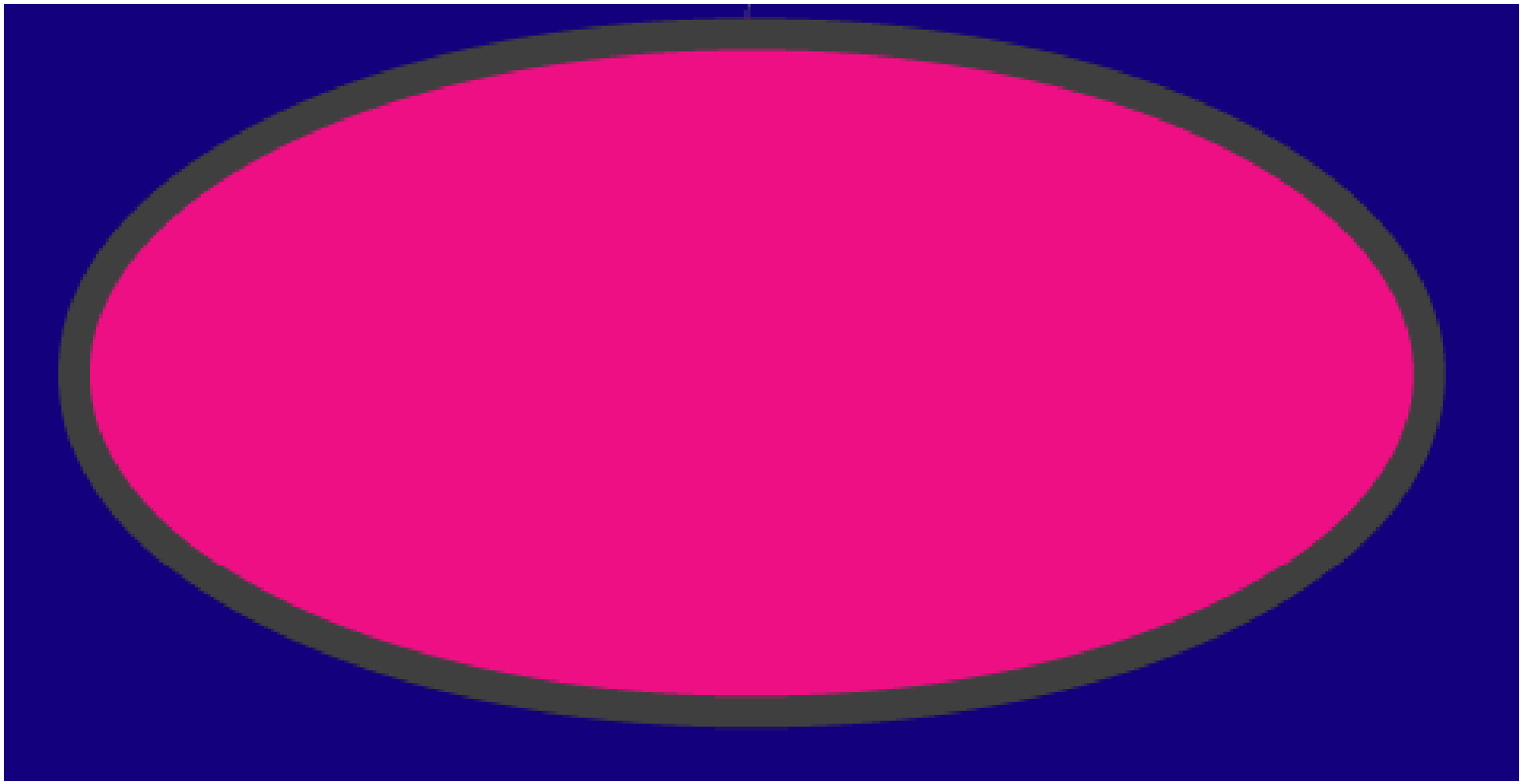
COBE, early 1990's

John Mather
2006 Nobel Prize

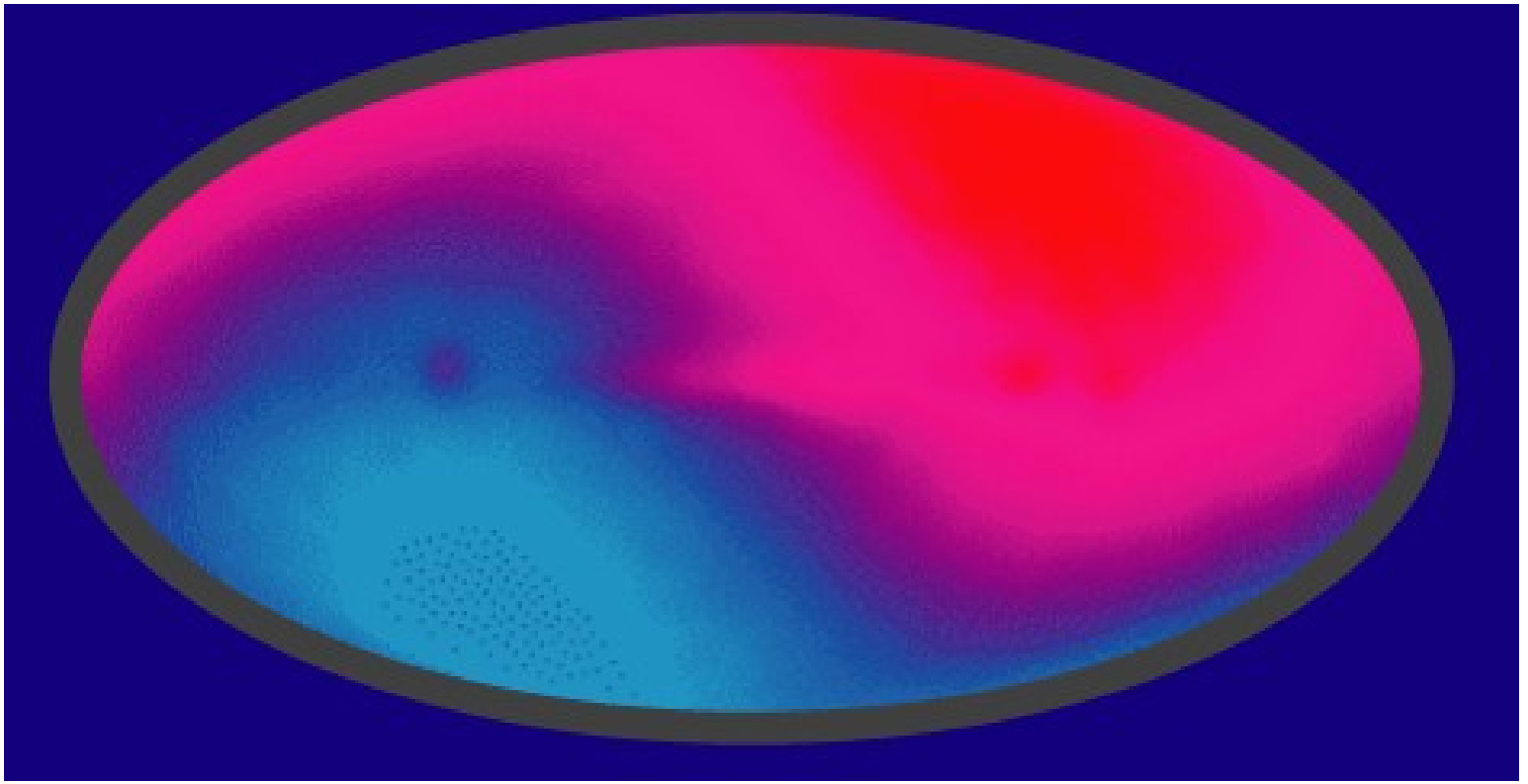
CMB Fun Facts

- ~400 photons per cm^3
- speed of light is large! 10^{13} photons per cm^2 per second!
- accounts for a few percent of the TV “snow” you see between stations (for those of you without cable…)

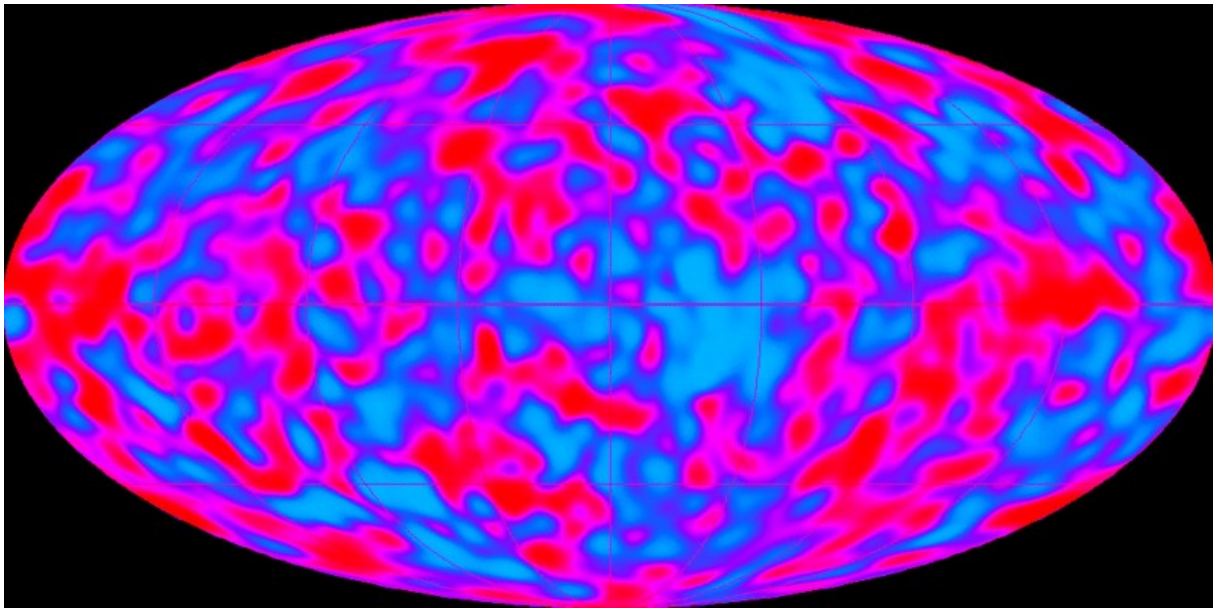
Monopole



Dipole



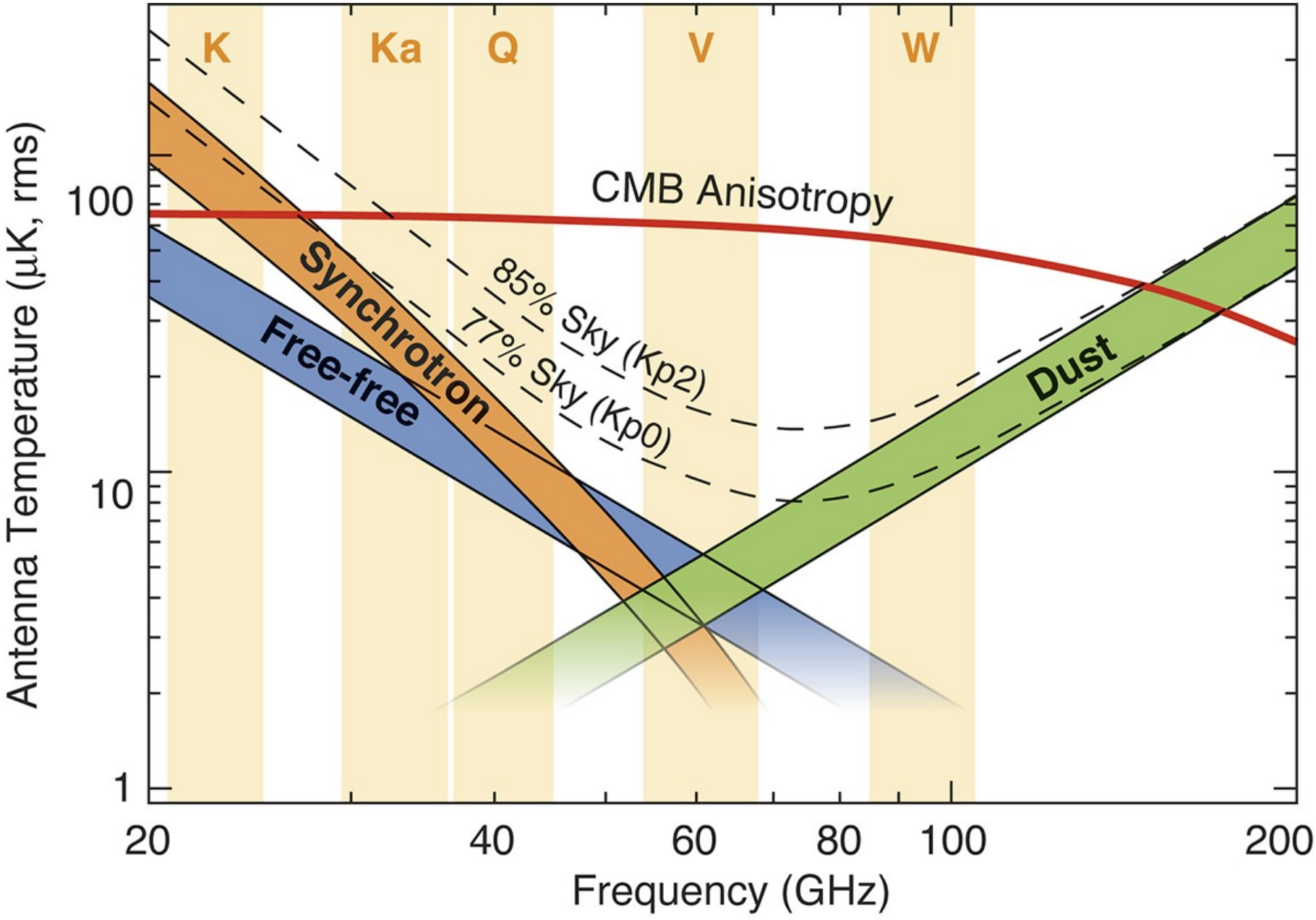
CoBE Satellite



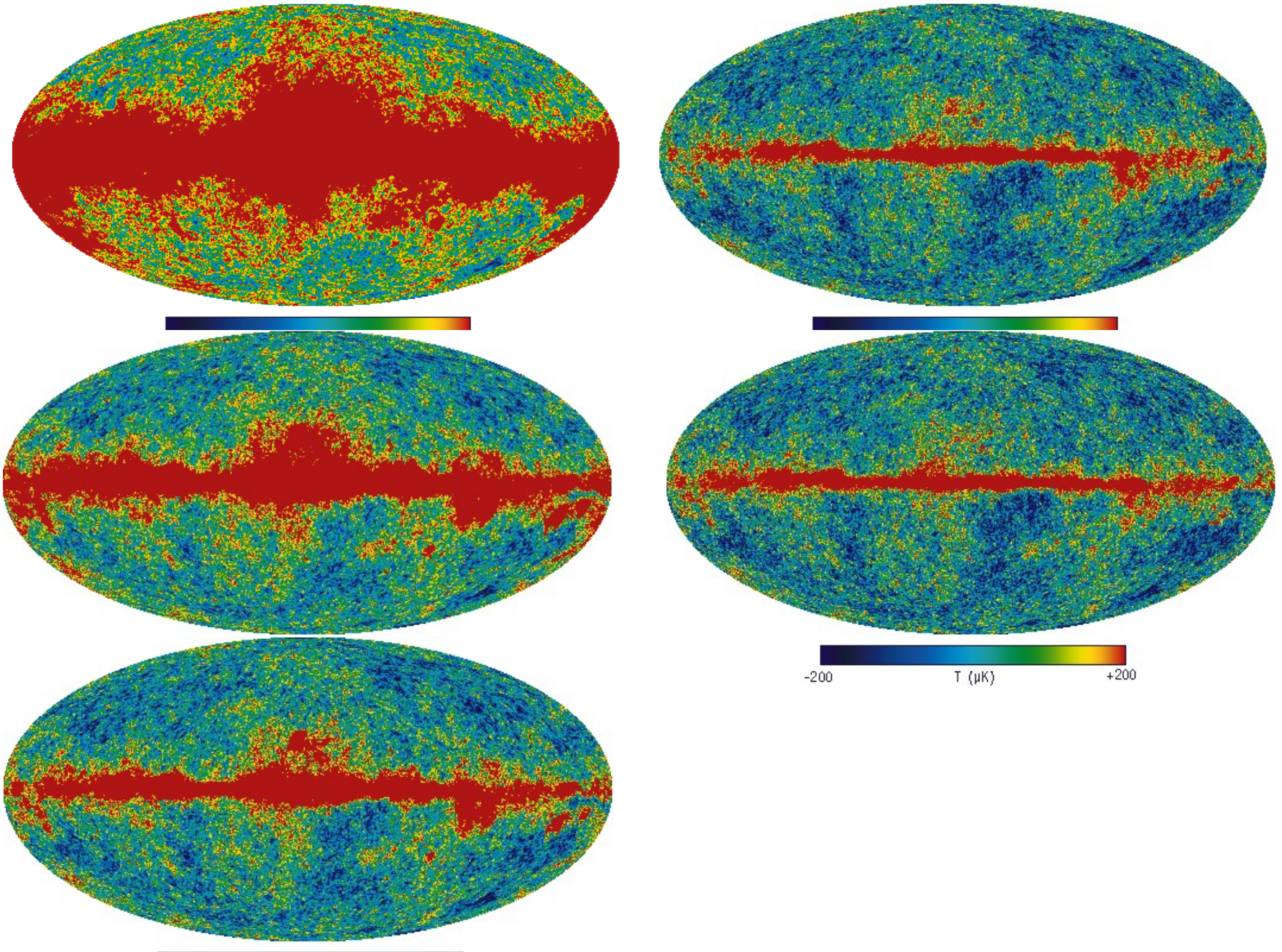
first map of CMB fluctuations, early 1990's, COBE mission

George Smoot
2006 Nobelist

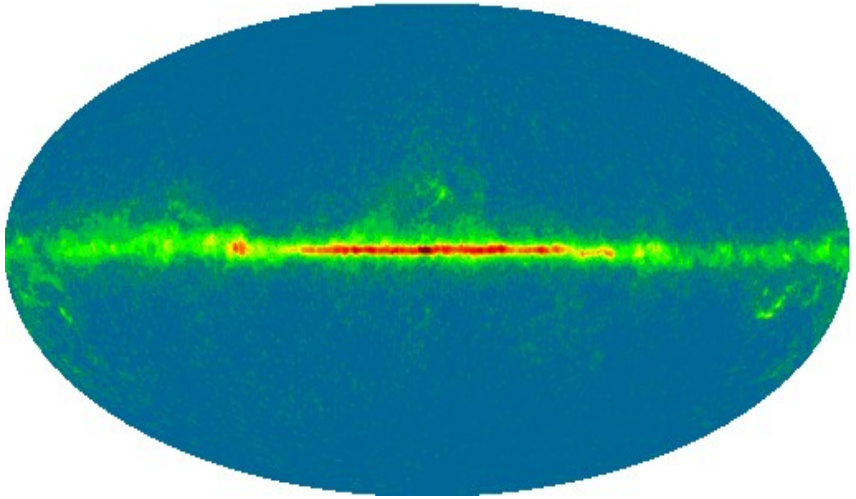
Foreground Removal



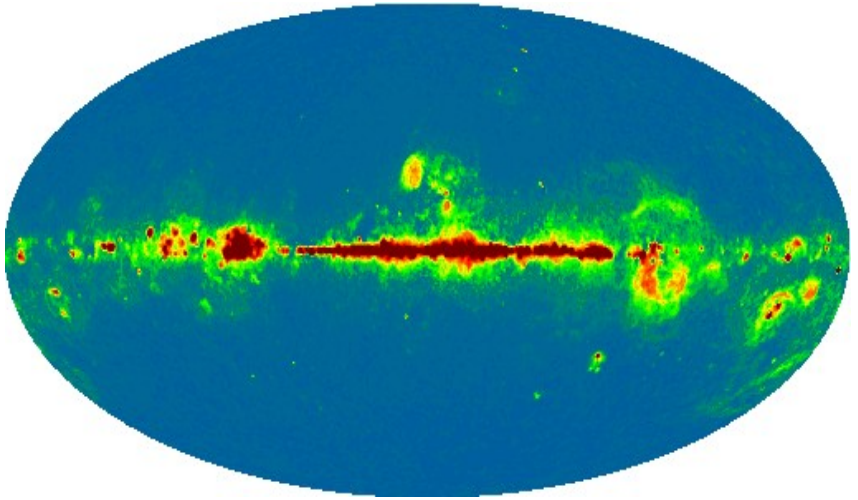
“Raw” Maps at 5 Wavelengths



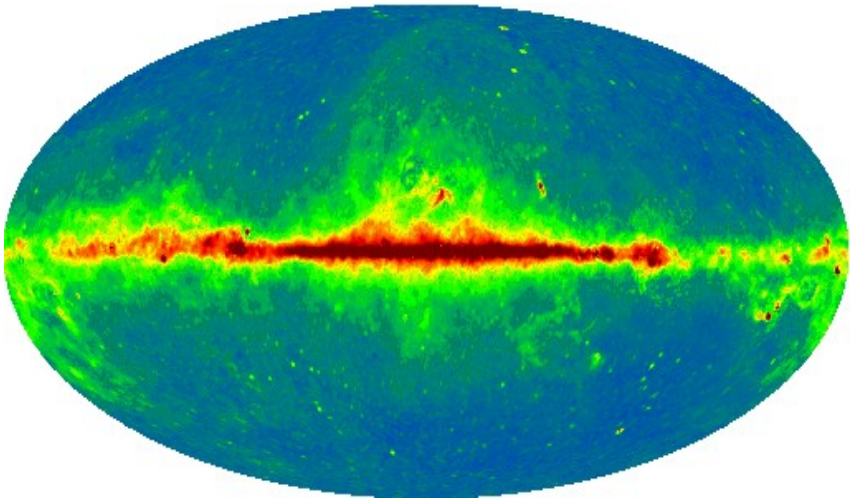
Foreground Models



dust

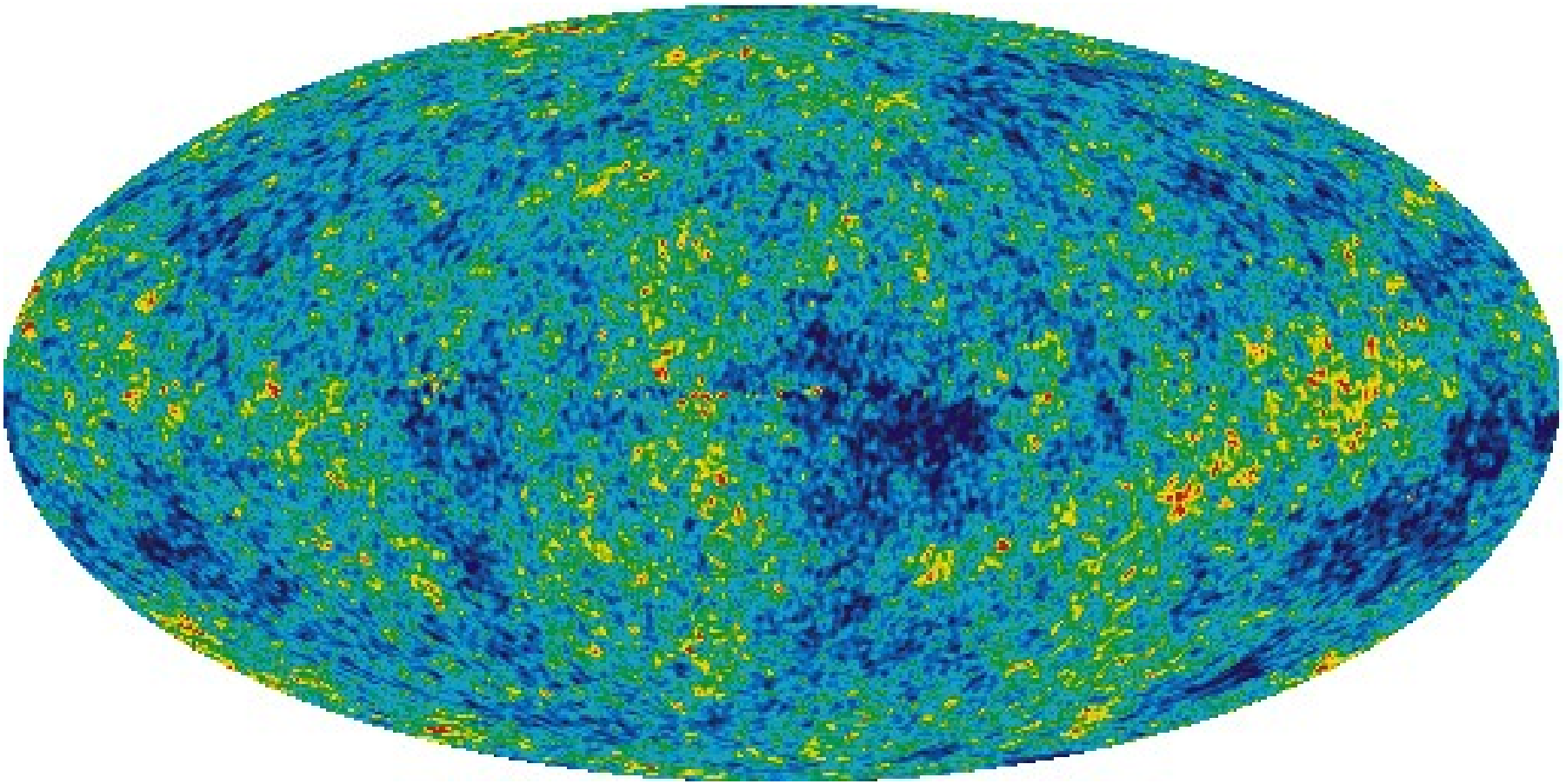


free-free

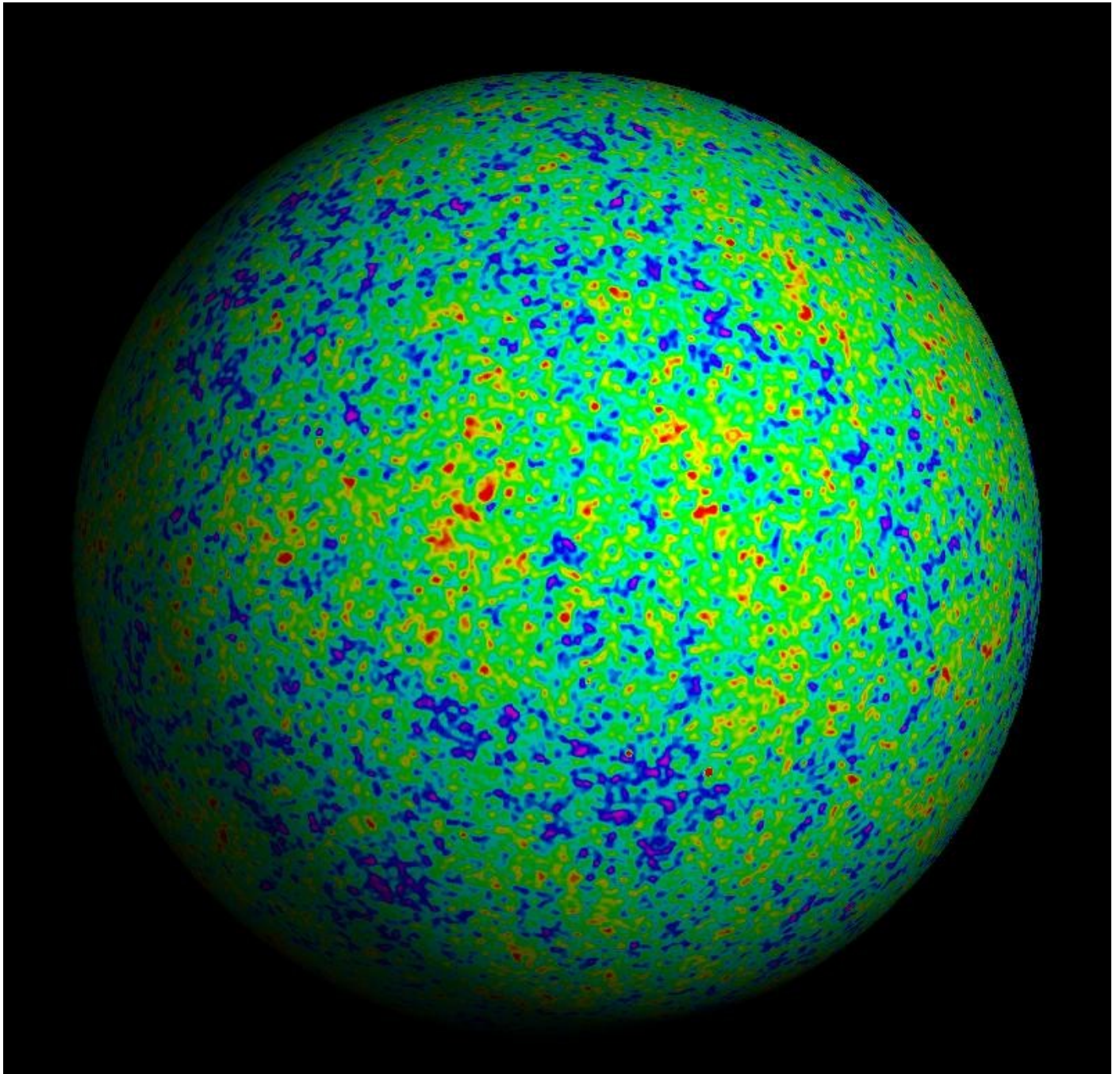


synchrotron

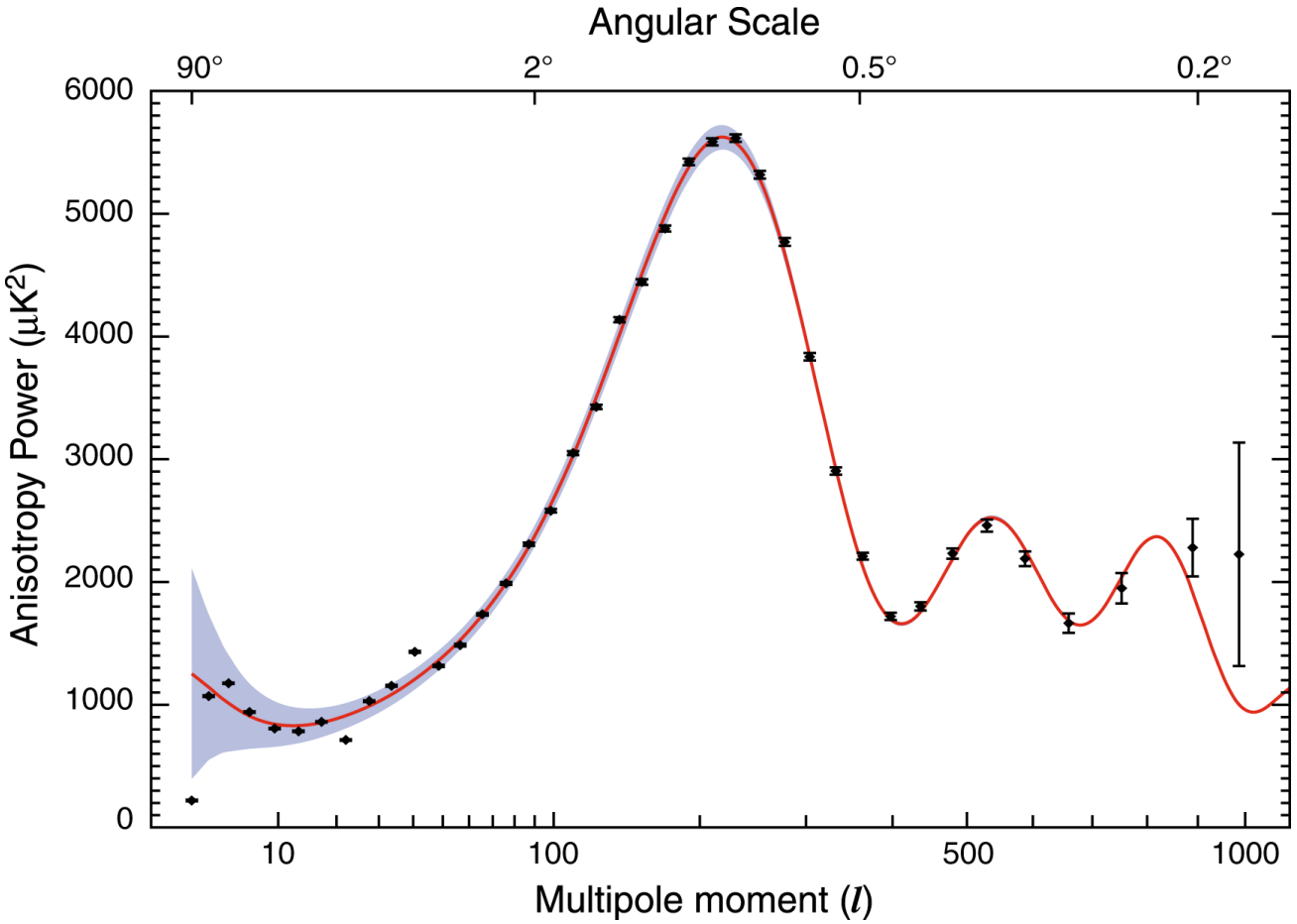
Foreground-subtracted

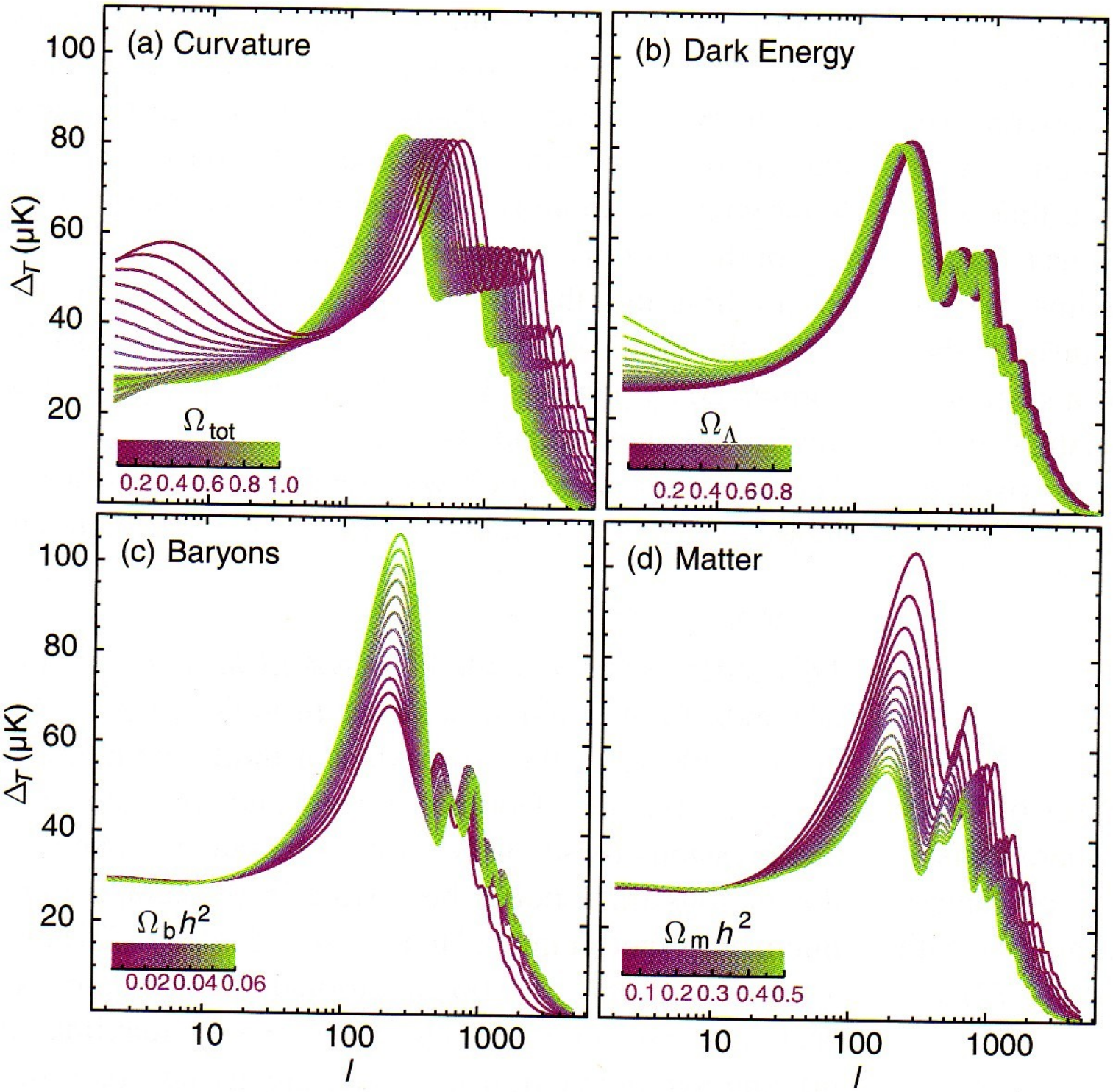


A Different View

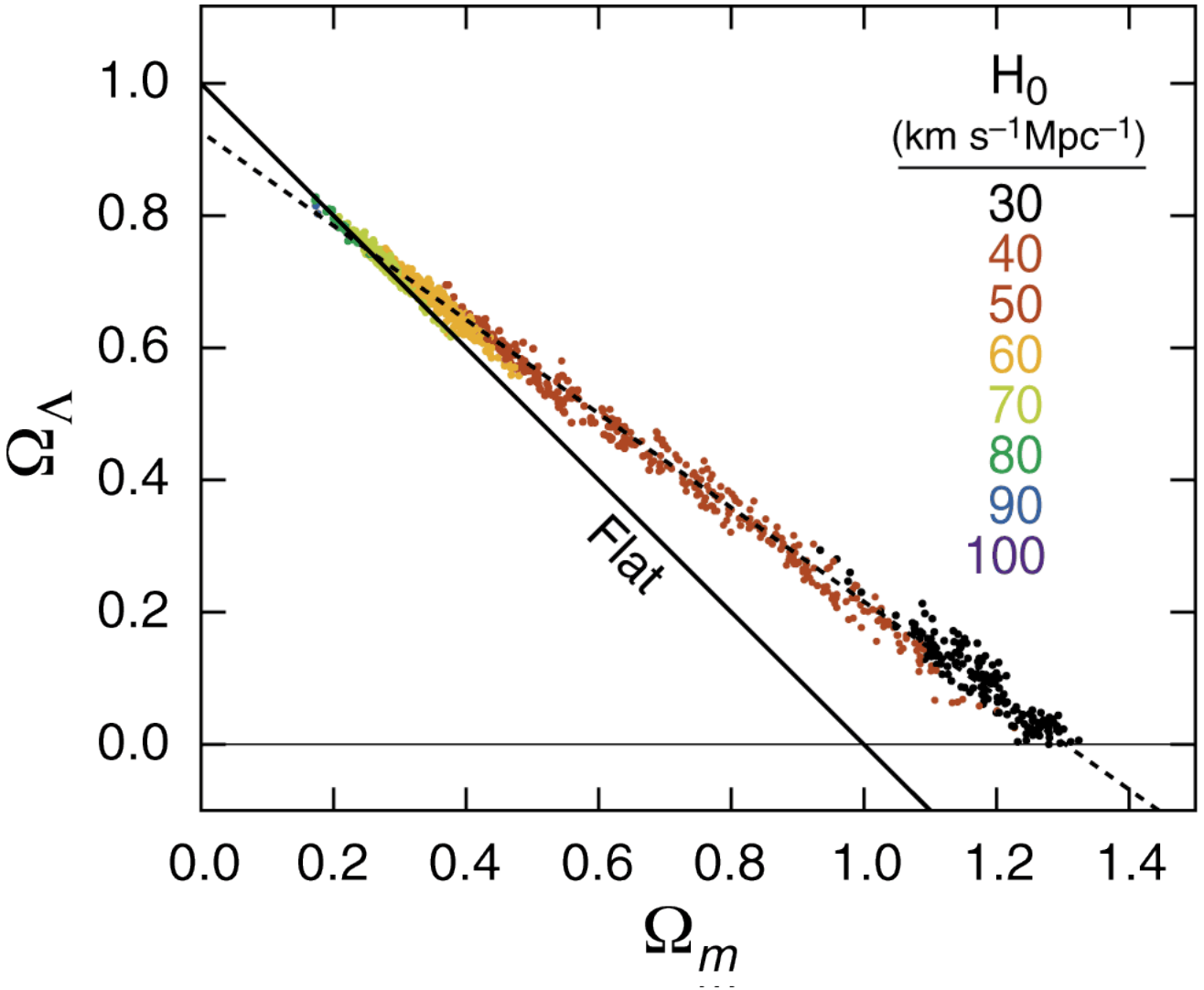


CMB Anisotropies (WMAP3)

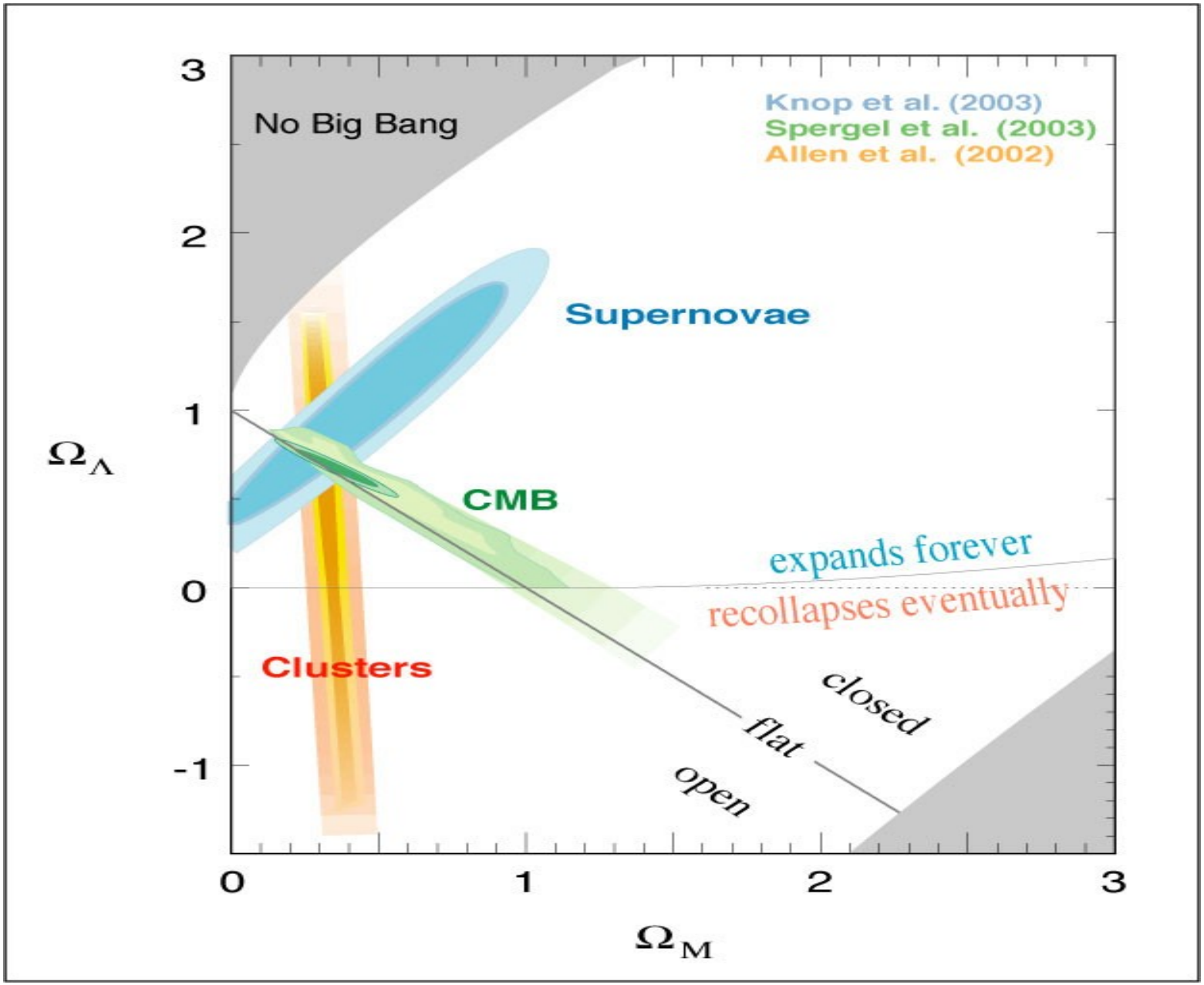



(a) Curvature
(b) Dark Energy
(c) Baryons
(d) Matter
Δ_T (μK)
100
80
60
40
20
Ω_{tot}
0.2 0.4 0.6 0.8 1.0
Ω_Λ
0.2 0.4 0.6 0.8
$\Omega_b h^2$
0.02 0.04 0.06
$\Omega_m h^2$
0.1 0.2 0.3 0.4 0.5
10
100
1000
l

WMAP3 Implications



WMAP Implications



WMAP Cosmological Parameters Model: lcdm Data: wmap	
$10^2\Omega_b h^2$	2.229 ± 0.073
$\Delta^2_{\mathcal{R}}(k = 0.002/\mathrm{Mpc})$	$(23.5 \pm 1.3) \times 10^{-10}$
h	$0.732^{+0.031}_{-0.032}$
H_0	$73.2^{+3.1}_{-3.2}$ km/s/Mpc
$\log(10^{10} A_s)$	3.156 ± 0.056
$n_s(0.002)$	0.958 ± 0.016
$\Omega_b h^2$	0.02229 ± 0.00073
$\Omega_c h^2$	$0.1054^{+0.0078}_{-0.0077}$
Ω_Λ	0.759 ± 0.034
Ω_m	0.241 ± 0.034
$\Omega_m h^2$	$0.1277^{+0.0080}_{-0.0079}$
σ_8	$0.761^{+0.049}_{-0.048}$
τ	0.089 ± 0.030
θ_A	0.5952 ± 0.0021 °
z_r	$11.0^{+2.6}_{-2.5}$

+derived quantities such as t0=13.7 Gyr