A candidate explanation for a parameter shift from WMAP9 to Planck

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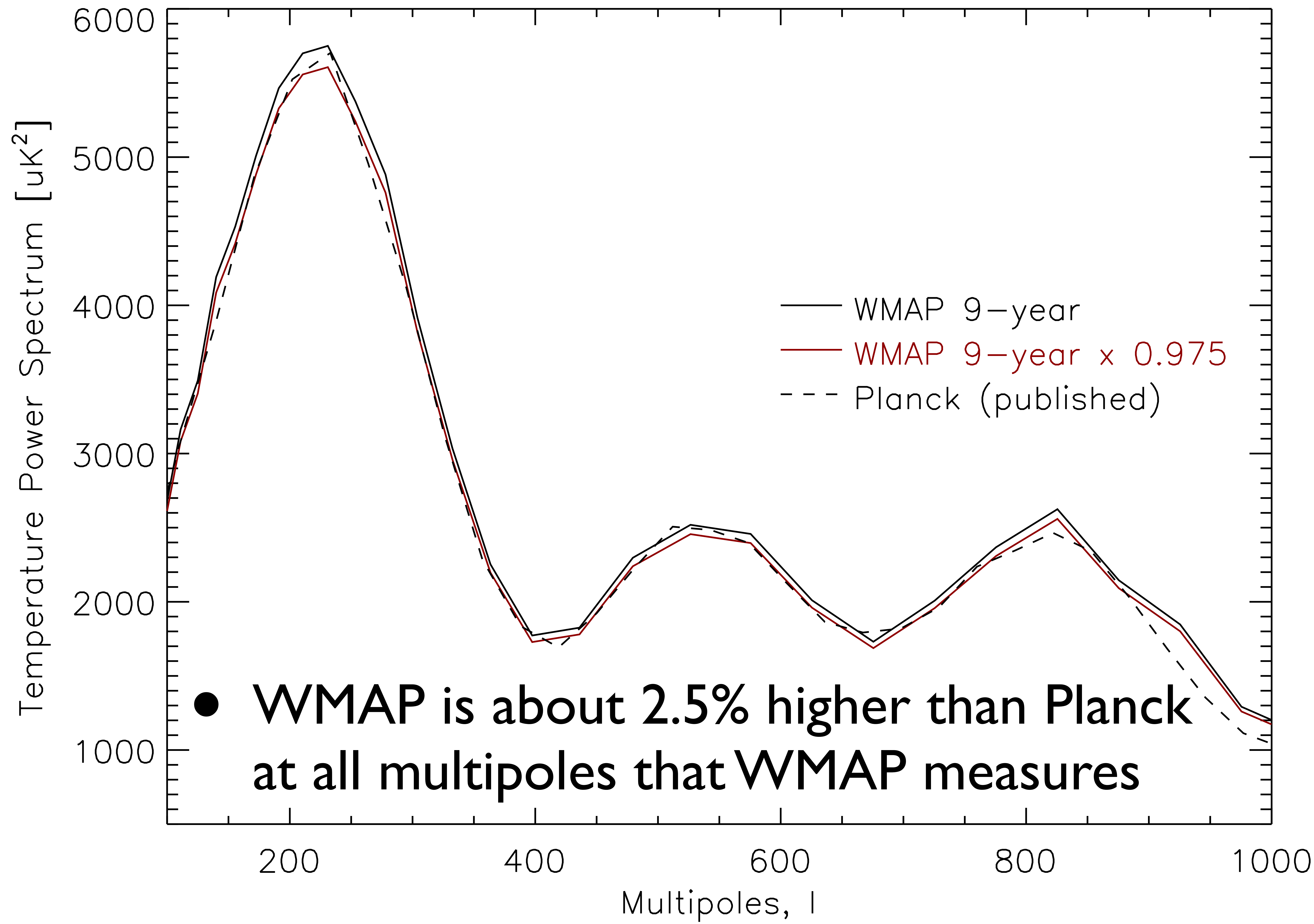
I was shocked when I saw these numbers on March 21

- Maximum likelihood values: WMAP9 to Planck+WP
- **$\Omega_m h^2$=0.1368 to 0.14305 [4.6% up]**
  - $\Omega_b h^2$=0.02256 to 0.02203 [2.4% down]
  - $\Omega_c h^2$=0.1142 to 0.1204 [5.4% up]
  - $\Omega_\nu h^2$=0 to 0.00062 [prior]
- **H_0=69.7 to 67.04 [4.0% down]**

Where does the change comes from?

- Maximum likelihood values: WMAP9 to Planck+WP
- Peak positions
  - Angular size of the acoustic scale: $\theta_*=0.0103889$ to 0.0104136 [0.2% up; peak positions are the same]
  - Related to this: $\Omega_m h^3=0.09532$ to 0.09591 [0.6% up; negligible compared to changes in $\Omega_m h^2$ or h]
- Primordial Amplitude [rescaled to k=0.05/Mpc]
  - $10^9\Delta_R^2 e^{-2\tau}=1.847$ to 1.8414 [0.3% down; negligible change in the inferred amplitude]

Now looking at the data...



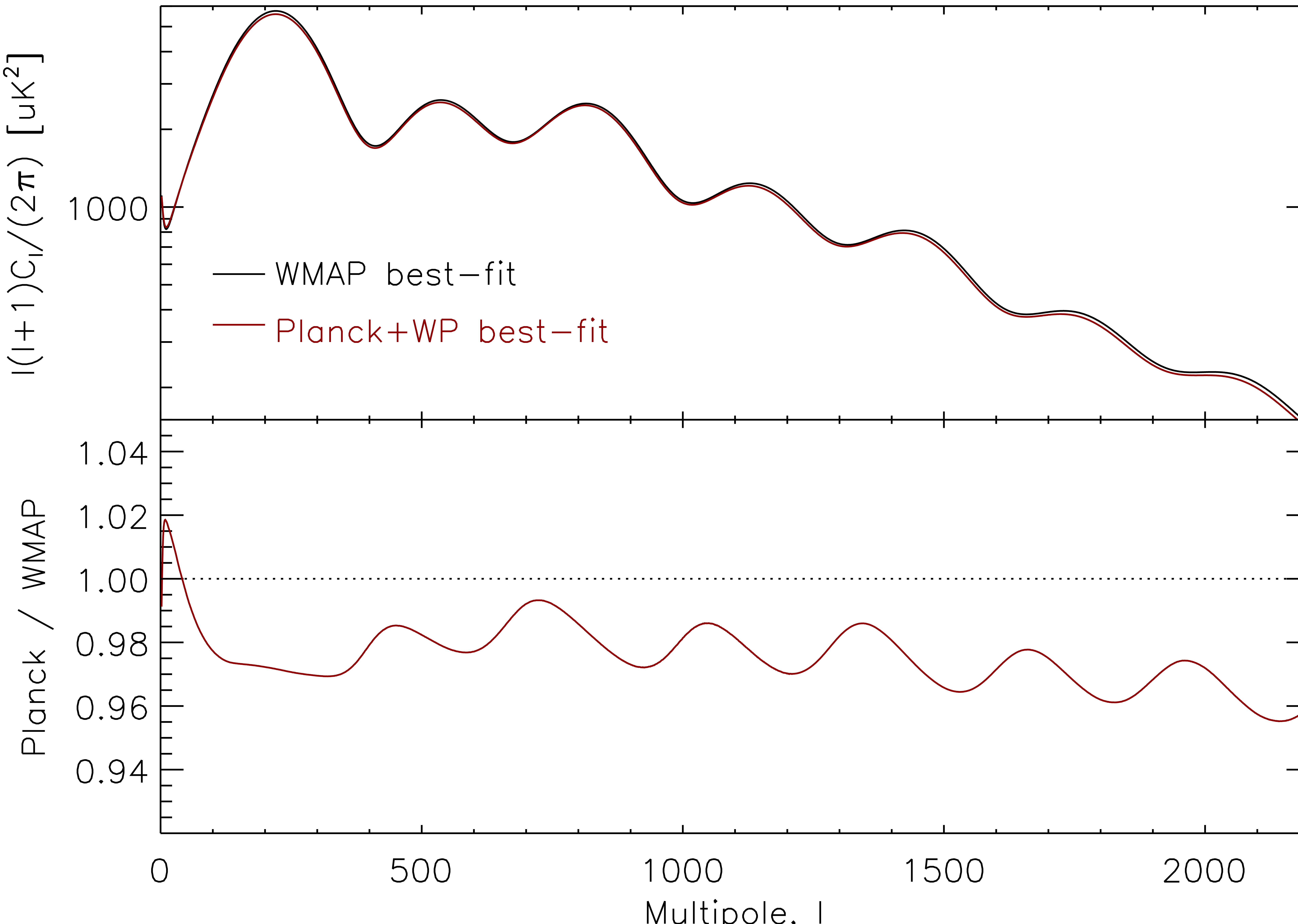
- WMAP is about 2.5% higher than Planck at all multipoles that WMAP measures

Where did the 2.5% go??

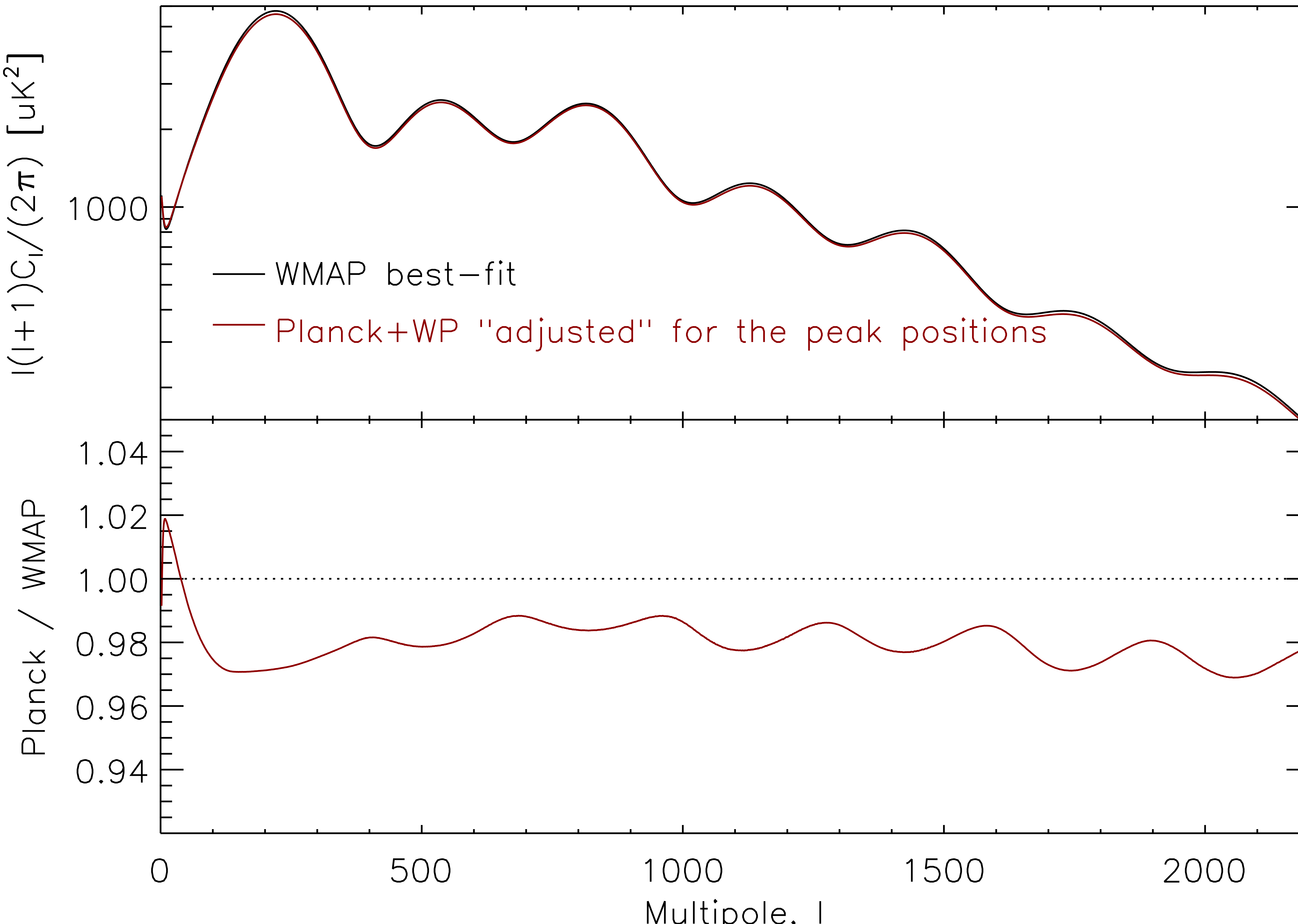
- Primordial Amplitude [rescaled to k=0.05/Mpc]
  - $10^9 \Delta_R^2 e^{-2\tau}$=1.847 to 1.8414 [0.3% down; negligible change in the inferred amplitude]
- Where did the 2.5% go??

Note

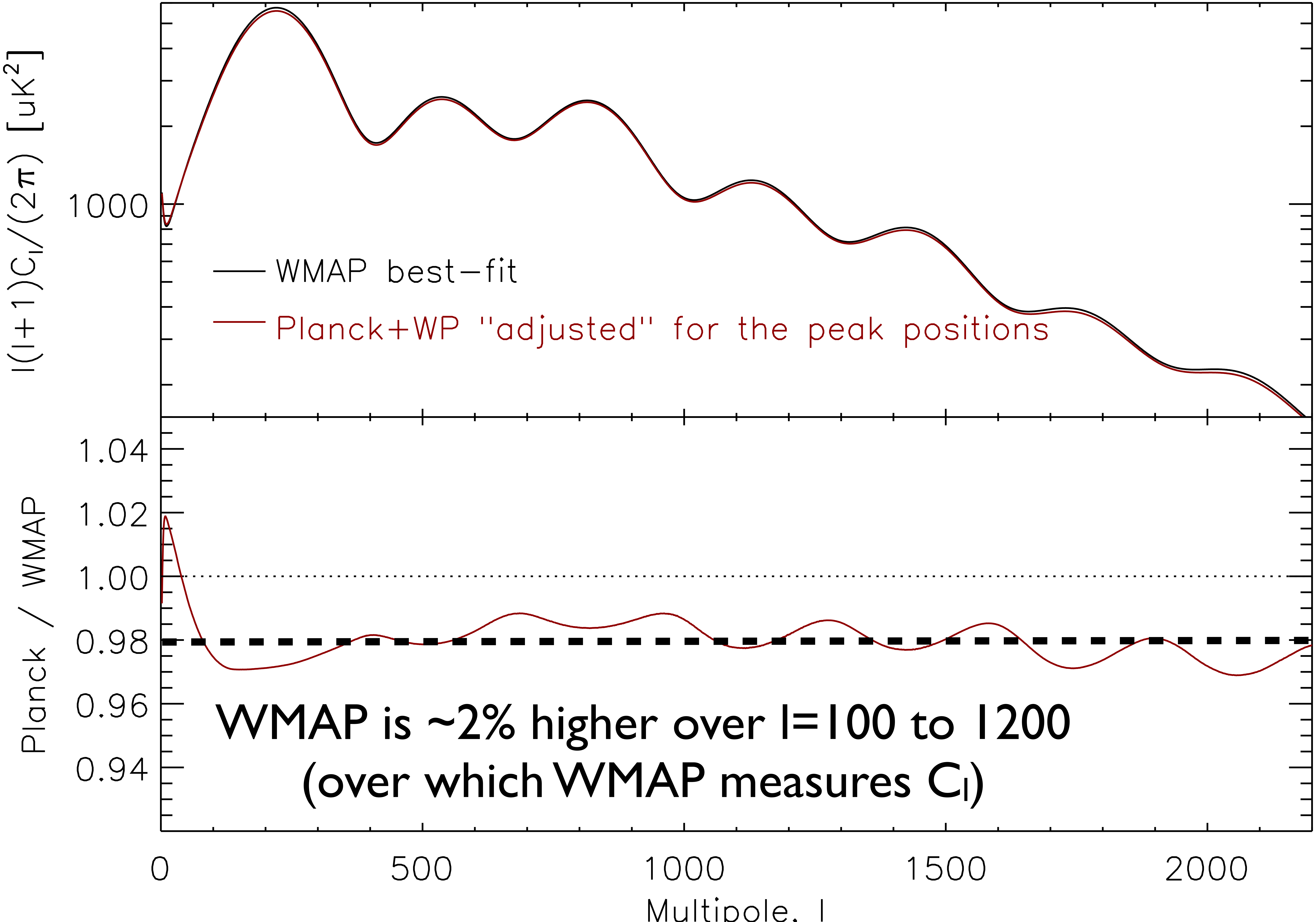
- The reason for this 2.5% offset in power is currently unknown.
  - This is the important issue to be resolved!
- In this presentation, I will ***not*** be talking about a resolution of this discrepancy.
  - I just want to know why the parameters changed, *except for the amplitude*.
  - If the only amplitude changed, I would understand. But what we see is a complete opposite...



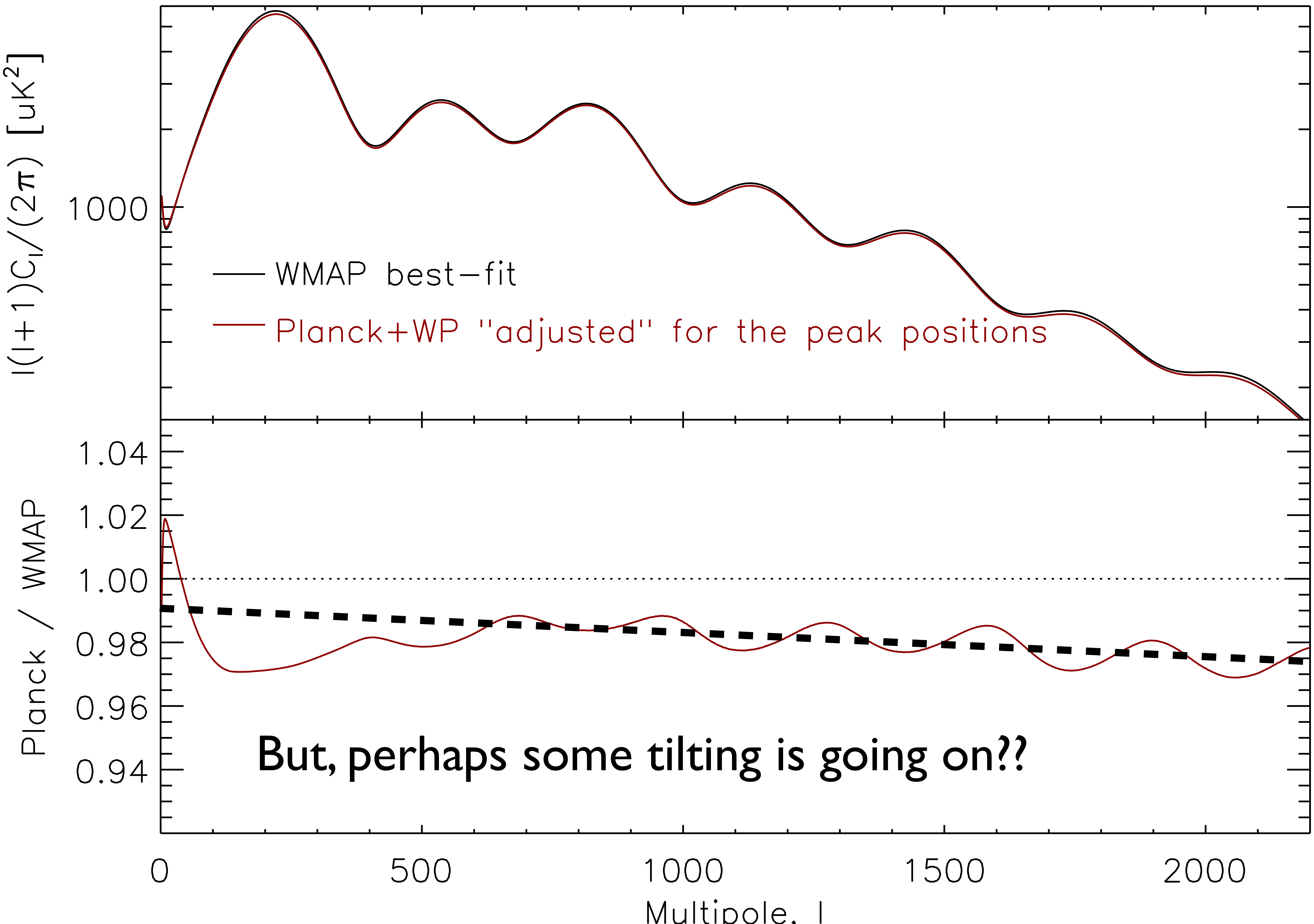
l(l+1)C_l/(2π) [uK^2]
1000
WMAP best-fit
Planck+WP best-fit
Planck / WMAP
1.04
1.02
1.00
0.98
0.96
0.94
0
500
1000
1500
2000
Multipole, l



l(l+1)C_l/(2π) [uK^2]
1000
WMAP best-fit
Planck+WP "adjusted" for the peak positions
Planck / WMAP
1.04
1.02
1.00
0.98
0.96
0.94
0
500
1000
1500
2000
Multipole, l

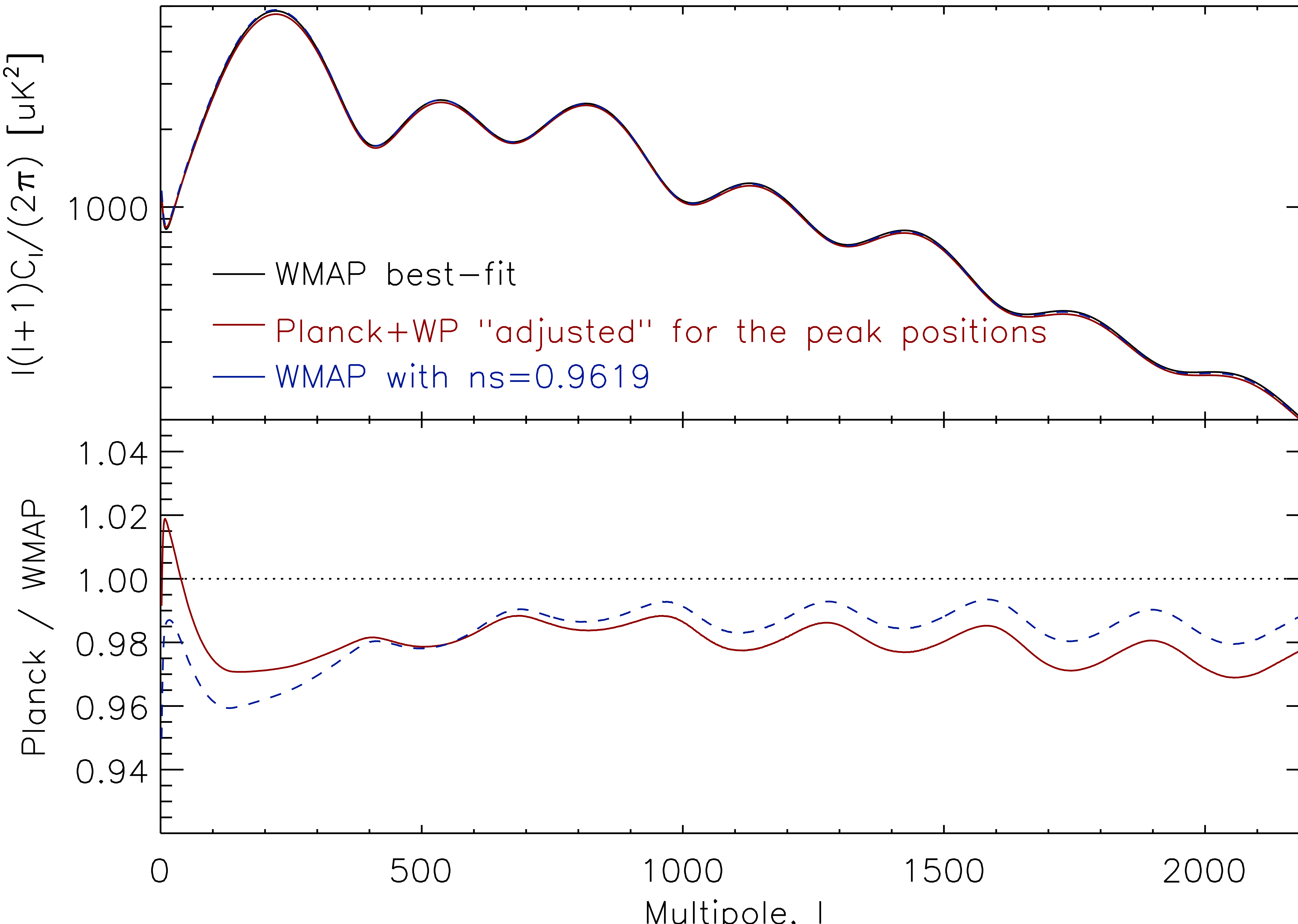


l(l+1)C_l/(2π) [uK^2]
1000
WMAP best-fit
Planck+WP "adjusted" for the peak positions
Planck / WMAP
1.04
1.02
1.00
0.98
0.96
0.94
WMAP is ~2% higher over l=100 to 1200
(over which WMAP measures C_l)
0
500
1000
1500
2000
Multipole, l


l(l+1)C_l/(2π) [uK^2]
1000
WMAP best-fit
Planck+WP "adjusted" for the peak positions
Planck / WMAP
1.04
1.02
1.00
0.98
0.96
0.94
But, perhaps some tilting is going on??
0
500
1000
1500
2000
Multipole, l

Tilt?

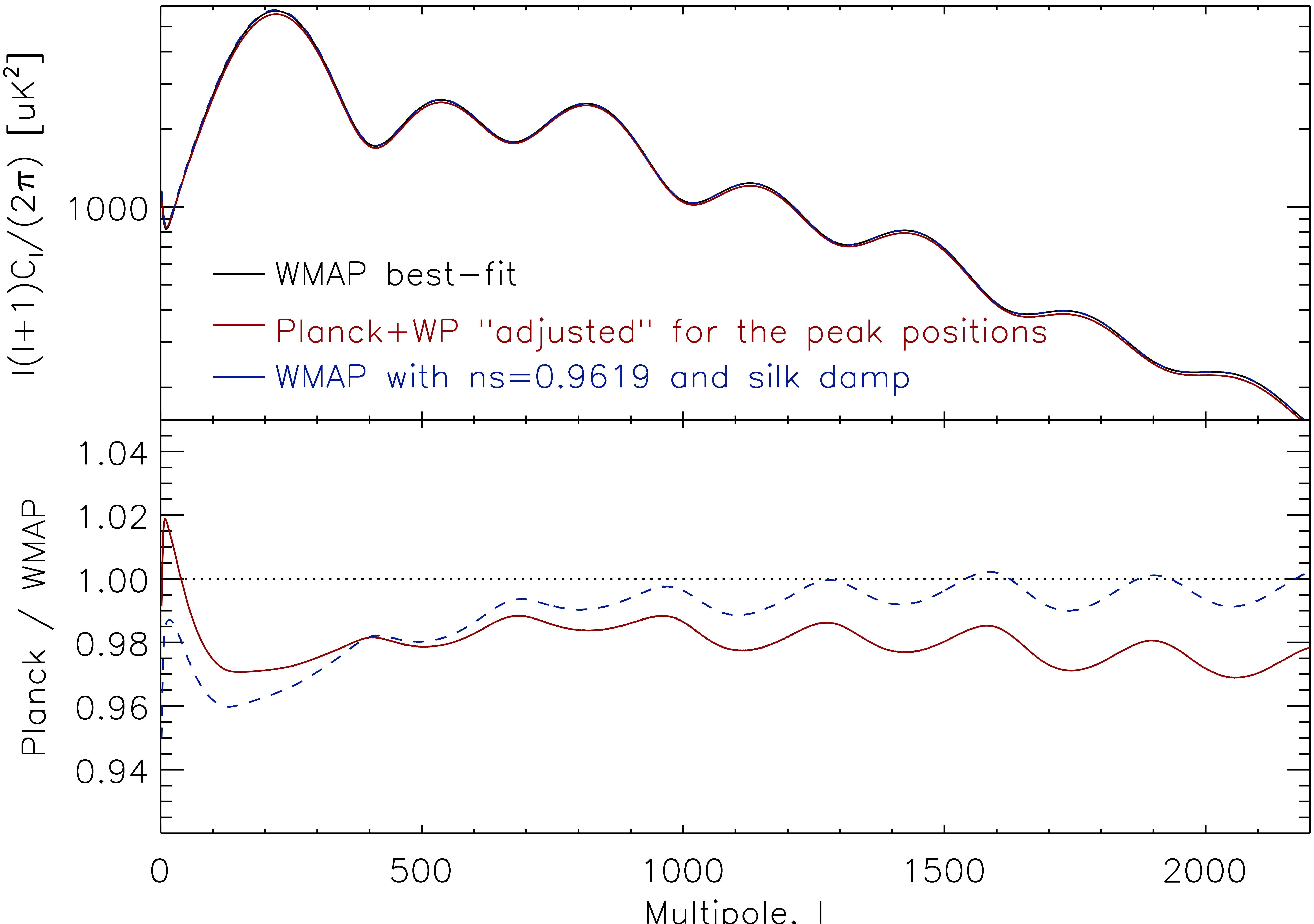
- Maximum likelihood value: WMAP9 to Planck
  - n_s=0.9710 to 0.9619



l(l+1)C_l/(2π) [uK^2]
1000
WMAP best-fit
Planck+WP "adjusted" for the peak positions
WMAP with ns=0.9619
Planck / WMAP
1.04
1.02
1.00
0.98
0.96
0.94
0
500
1000
1500
2000
Multipole, l

Silk damping?

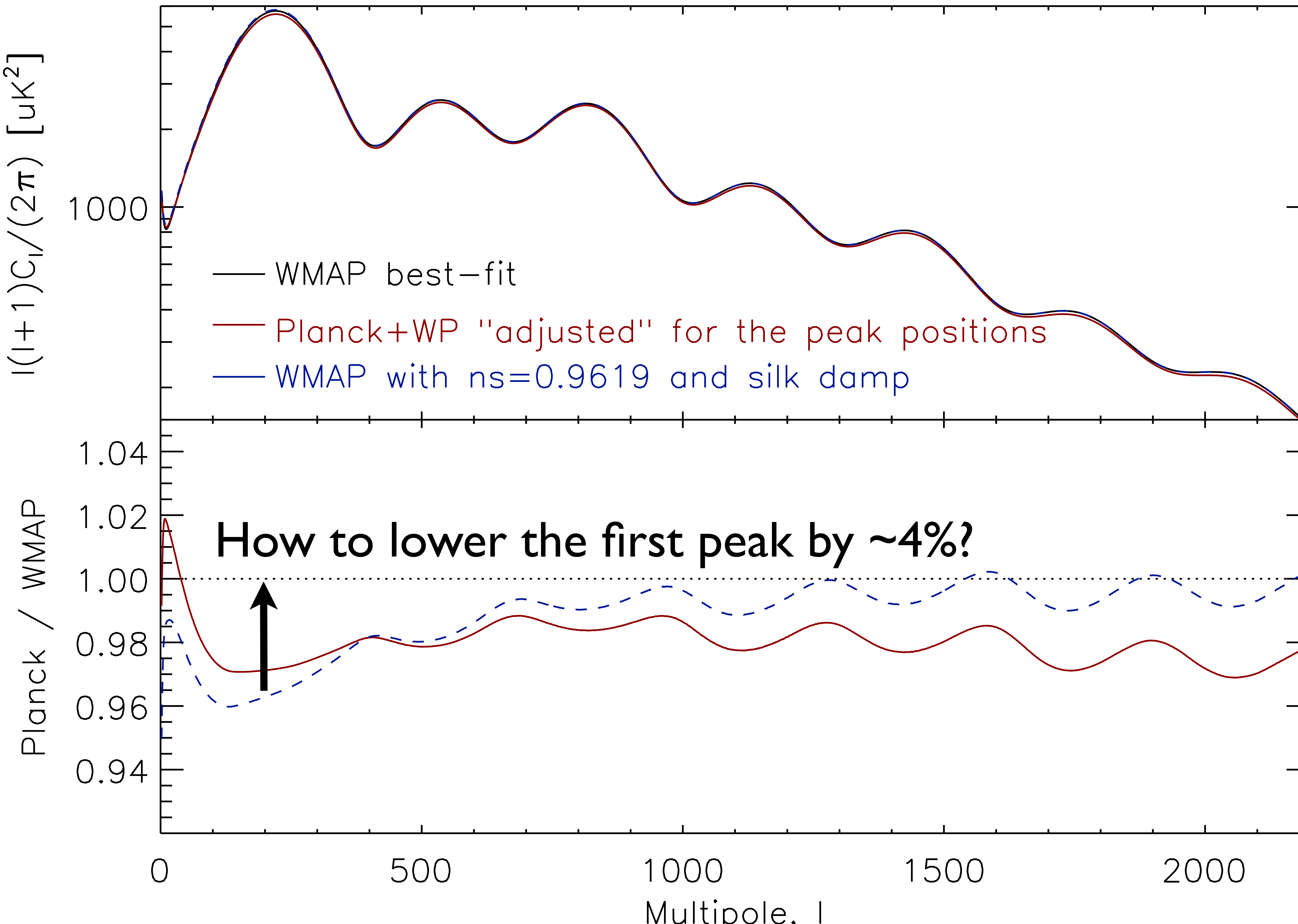
- The Silk damping damps C_l by $\exp(-2[l\theta_D/\pi]^{1.2})$
- Maximum likelihood value: WMAP9 to Planck
  - θ_D=0.16063 to 0.16138 [0.5% larger]
  - Planck's 1-σ error bar on θ_D is 0.4%
- Seems small, but since it is in the exponential...



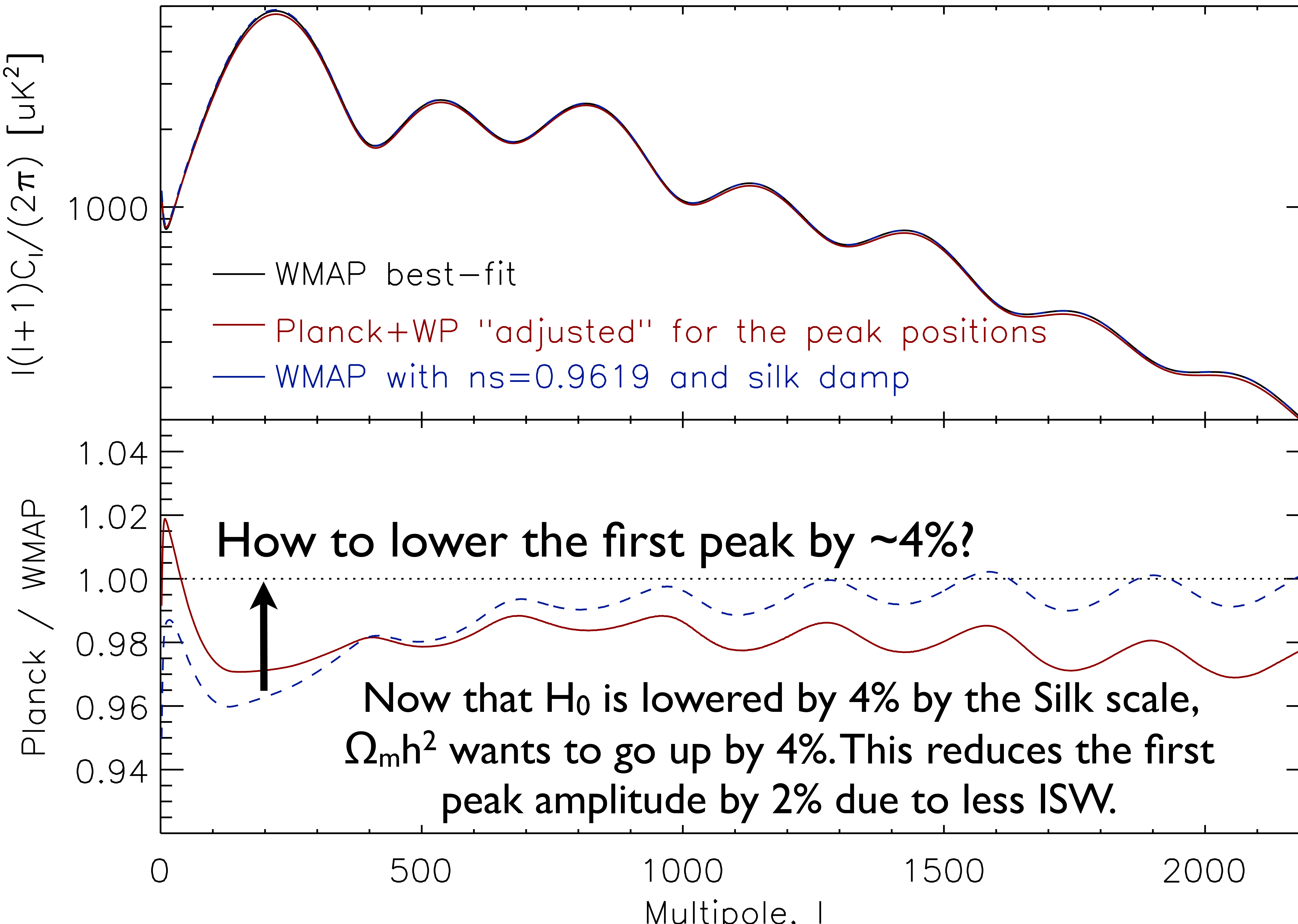
l(l+1)C_l/(2π) [uK^2]
1000
WMAP best-fit
Planck+WP "adjusted" for the peak positions
WMAP with ns=0.9619 and silk damp
Planck / WMAP
1.04
1.02
1.00
0.98
0.96
0.94
0
500
1000
1500
2000
Multipole, l

What does it take to change the Silk scale?

- Very subtle... According to Hu et al. (2008):
- $\Delta\theta_D/\theta_D \approx 0.12\Delta(\Omega_m h^3)/(\Omega_m h^3) - 0.20\Delta(\Omega_b h^2)/(\Omega_b h^2) + 0.06\Delta H_0/H_0$
- +0.6% in $\Omega_m h^3$; –2.4% in $\Omega_b h^2$; –4.0% in H_0 yields +0.3% in θ_D. Not too far away.
- *Perhaps the Silk scale is driving a parameter shift?*
    - (But it is degenerate...)

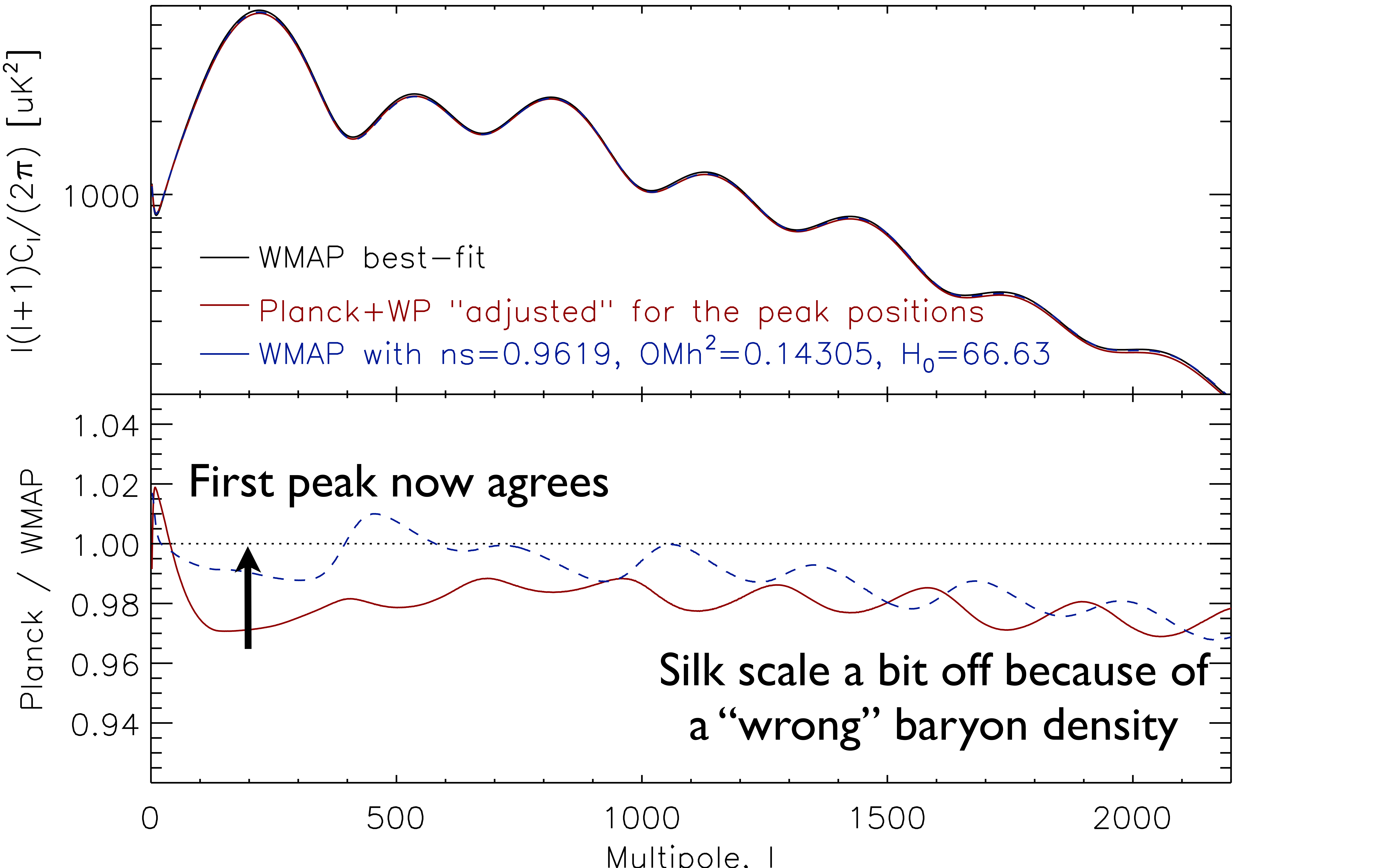


l(l+1)C_l/(2π) [uK^2]
1000
WMAP best-fit
Planck+WP "adjusted" for the peak positions
WMAP with ns=0.9619 and silk damp
Planck / WMAP
1.04
1.02
1.00
0.98
0.96
0.94
How to lower the first peak by ~4%?
0
500
1000
1500
2000
Multipole, l


l(l+1)C_l/(2π) [uK^2]
1000
WMAP best−fit
Planck+WP "adjusted" for the peak positions
WMAP with ns=0.9619 and silk damp
Planck / WMAP
1.04
1.02
1.00
0.98
0.96
0.94
How to lower the first peak by ~4%?
Now that H0 is lowered by 4% by the Silk scale,
Ωmh2 wants to go up by 4%. This reduces the first
peak amplitude by 2% due to less ISW.
0
500
1000
1500
2000
Multipole, l

Just to make a point...

- Just to show you how ISW does the job, let me do the following:
  - Do not touch the baryon density (so, the Silk scale would be a bit wrong)
  - Raise the CDM density to get the Planck total matter density
  - Keep $\Omega_m h^3$ fixed -> H_0 goes down to 66.63 km/s/Mpc



l(l+1)C_l/(2π) [uK^2]
1000
WMAP best−fit
Planck+WP "adjusted" for the peak positions
WMAP with ns=0.9619, OMh^2=0.14305, H_0=66.63
Planck / WMAP
1.04
1.02
1.00
0.98
0.96
0.94
First peak now agrees
Silk scale a bit off because of
a "wrong" baryon density
0
500
1000
1500
2000
Multipole, l

Conclusion

- Why did the amplitude not change from WMAP to Planck despite an overall 2.5% offset between them?
  - Somehow the data want a more complicated combination of parameters than just the amplitude.
- Three players: tilt, Silk scale, and early ISW
- It seems that the Silk scale drives changes in parameters (baryon and total matter density, as well as H_0)
  - But it is a degenerate problem...