Status of Planck
&
Prospects for B-mode with Planck

Andrew Lange & Kris Gorski

Chicago CMB Polarization Workshop

July 1, 2009

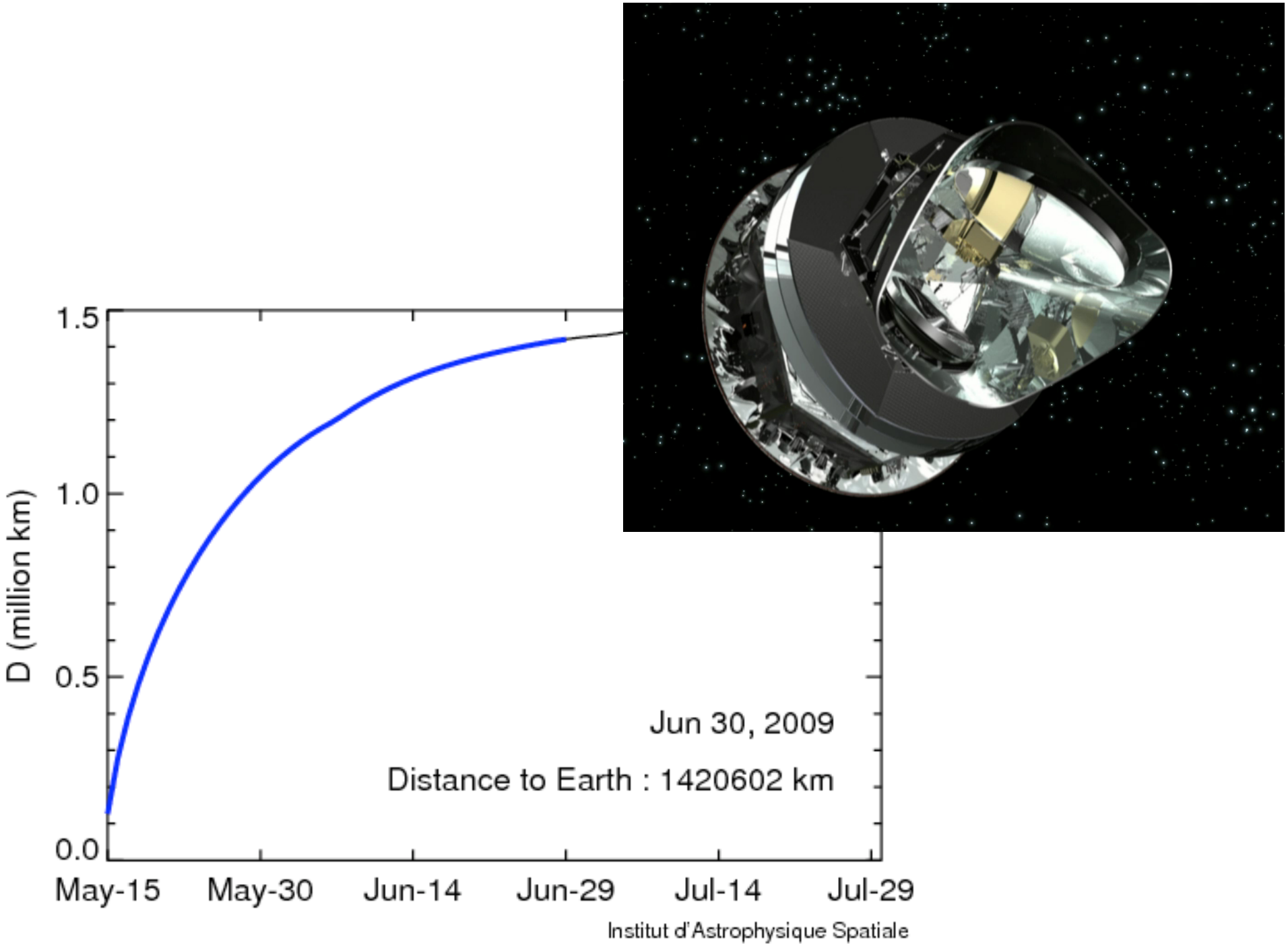
($T_{bolometer}$~ 150 mK)

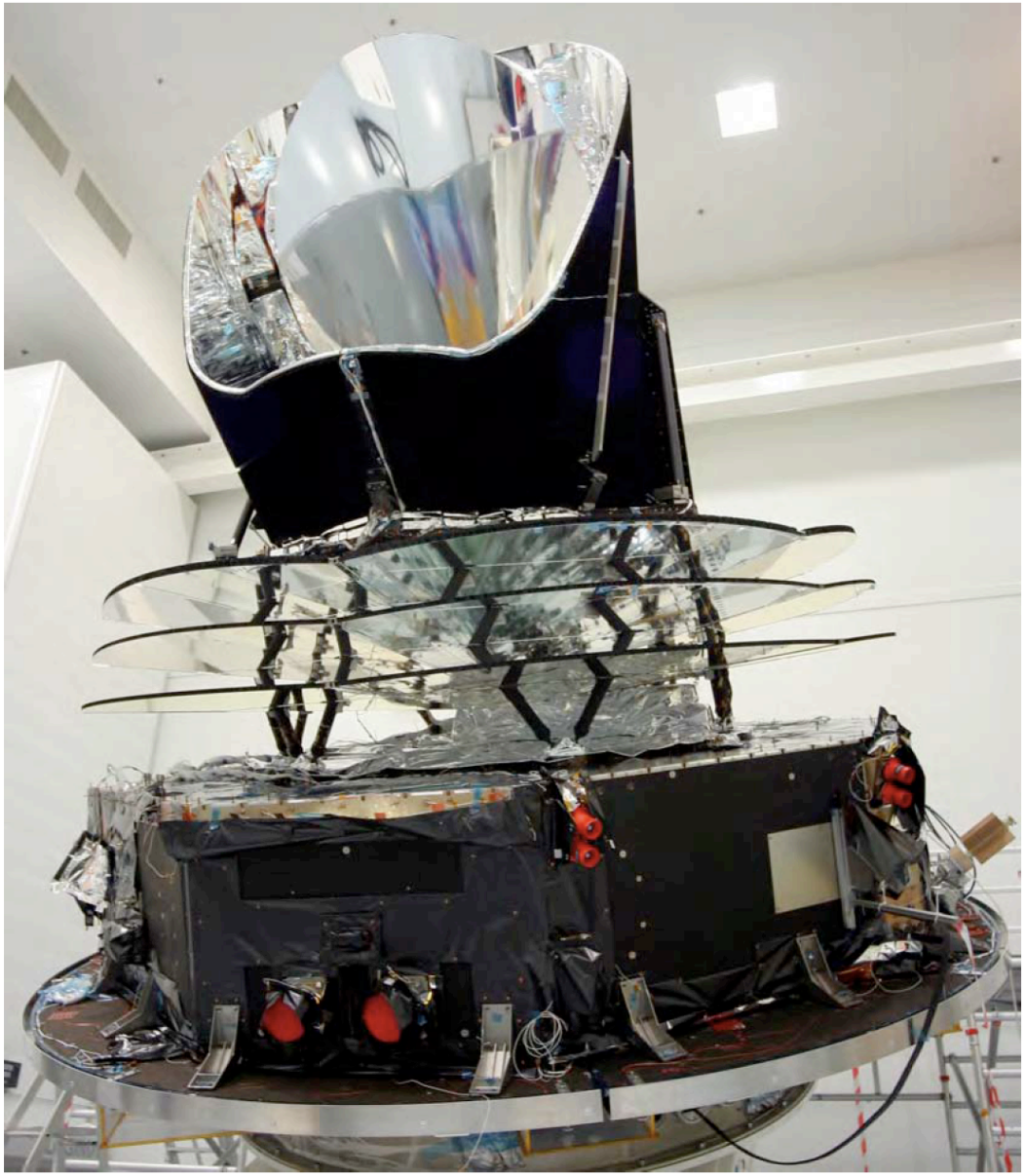
Planck

- Third generation space CMB mission
- Design goal is to measure the temperature anisotropies of the CMB to fundamental limits on all scales down to 5′. Polarization is important, and a matter of intense effort. But when choices had to be made, polarization was not a design driver.
- Will launch with Herschel on an Ariane 5 rocket
- Two instruments
  - Low Frequency Instrument (LFI), PI=Reno Mandolesi, IASF
  - High Frequency Instrument (HFI), PI=Jean-Loup Puget, IAS
- Current launch date 31 October 2008 

Planck is on orbit!

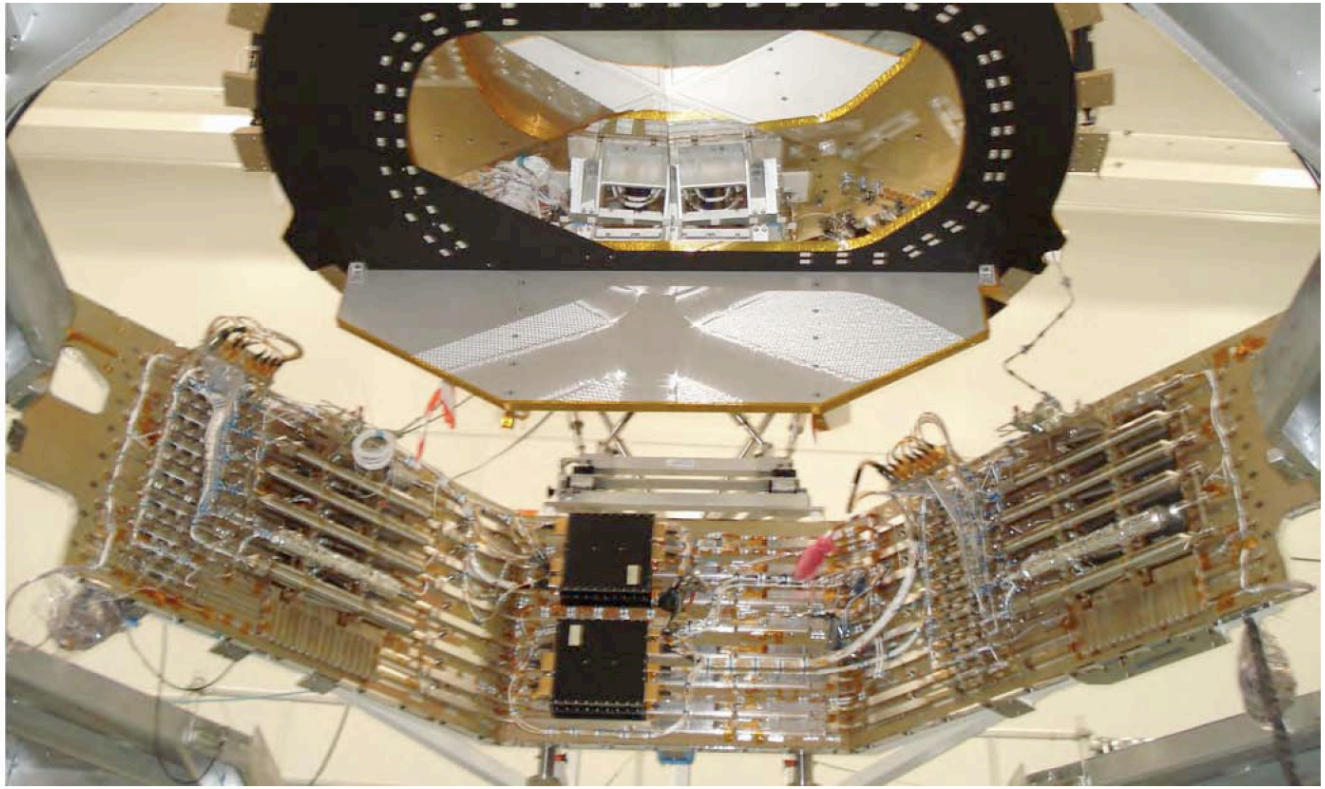
(Launched 5/14 6:12 AM PDT)


1.5
1.0
0.5
0.0
D (million km)
May-15
May-30
Jun-14
Jun-29
Jul-14
Jul-29
Jun 30, 2009
Distance to Earth : 1420602 km
Institut d'Astrophysique Spatiale



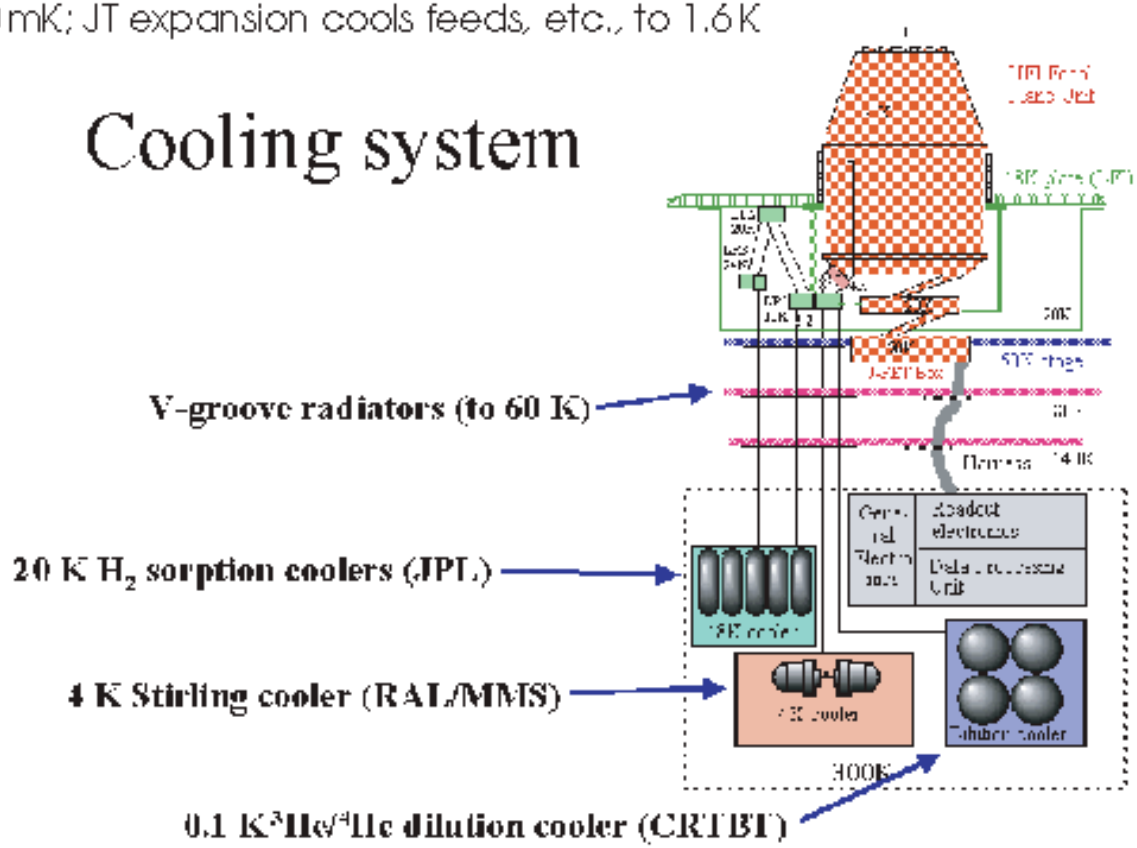
Cryogenics

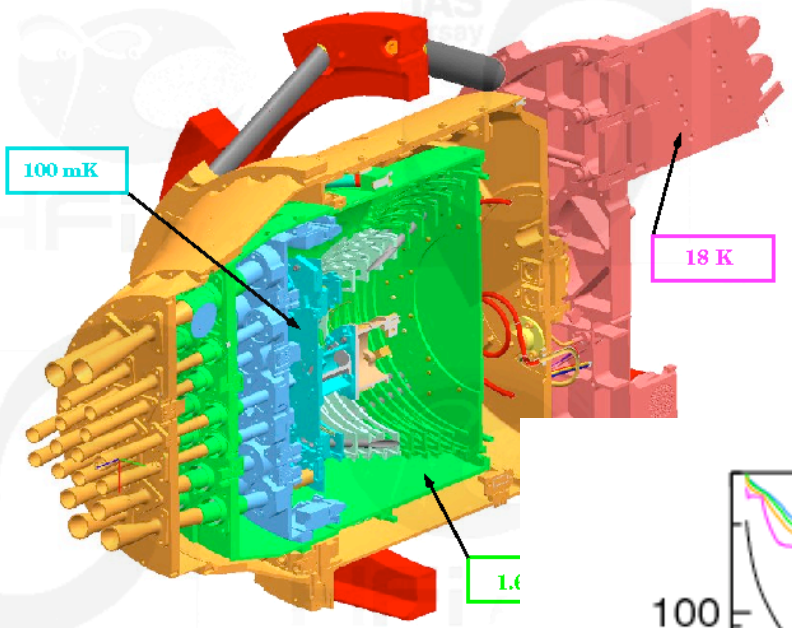
- Planck will be the first cryogenic astrophysics mission without cryogens
- 20 K hydrogen sorption cooler (fully redundant)
  - Cools LFI to $\lesssim 20$ K
  - Provides precooling to HFI at ~ 18 K

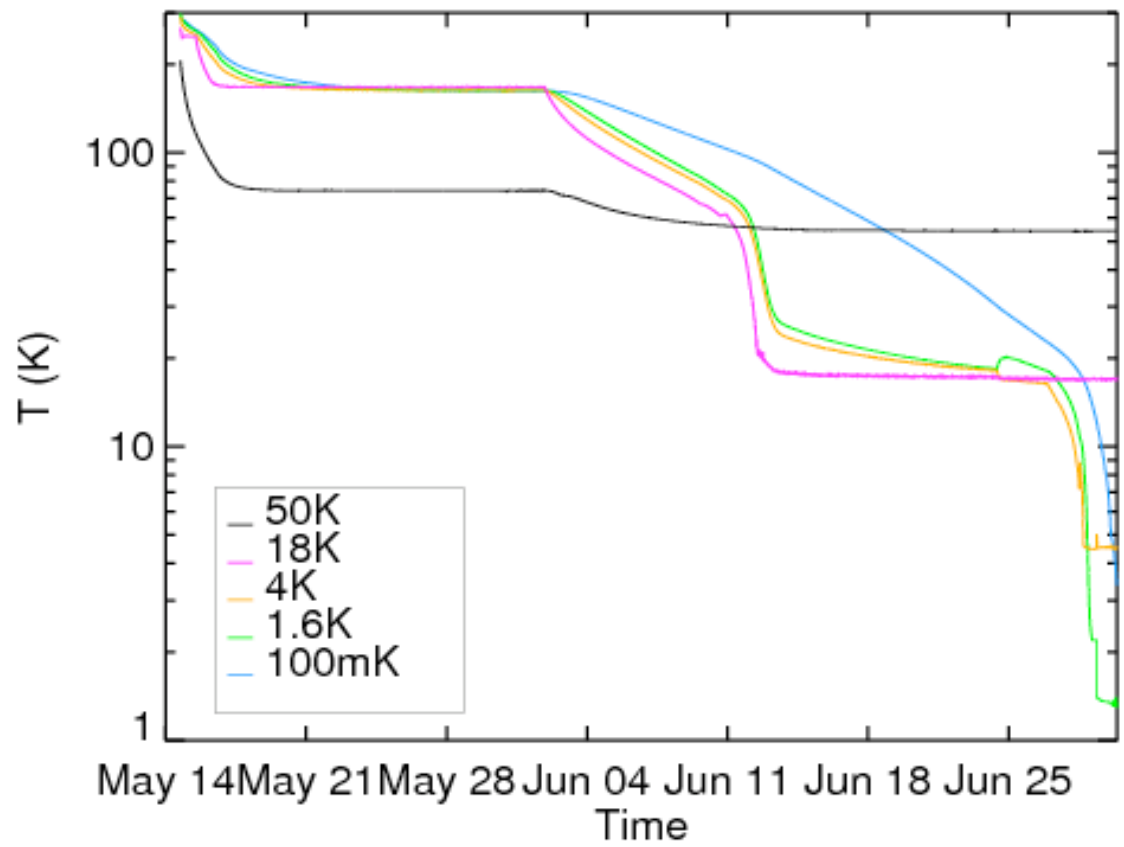


Cryogenics — cont'd

- 4 K ^{4}He JT cooler
  - Cools overall HFI structure to ~ 4 K; precools gas for dilution cooler; cools LFI cold loads
- 0.1 K ^{3}He–^{4}He dilution cooler
  - Cools bolometers to 100 mK; JT expansion cools feeds, etc., to 1.6 K







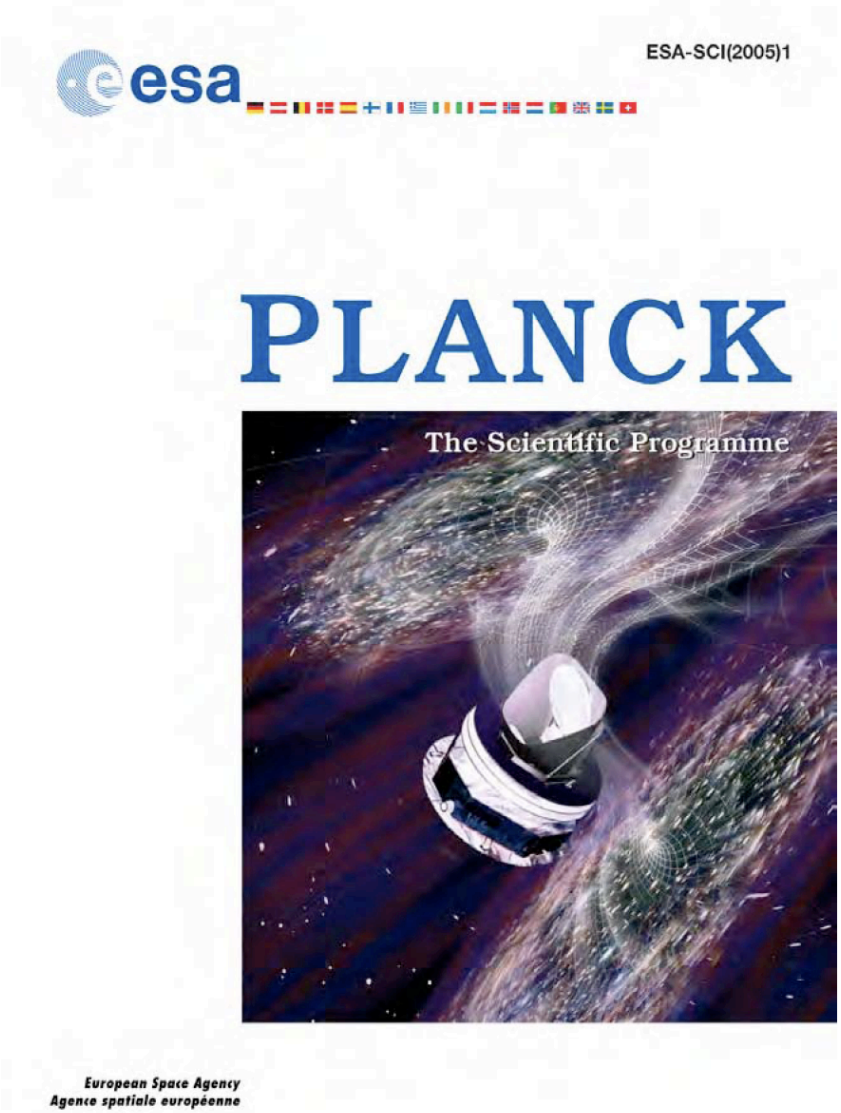
Institut d'Astrophysique Spatiale

Source of Information

- All information about Planck performance in this talk is from the Planck "Bluebook"

Google planck bluebook

- A performance update will be issued following the system-level cryo test in late spring



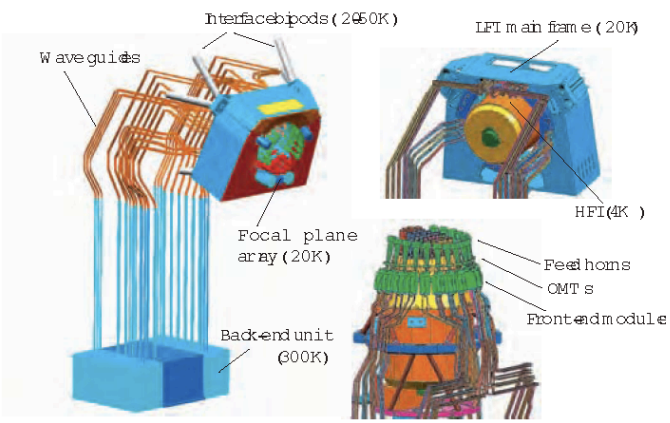
Instruments

Instrument Characteristic	LFI			HFI					
Detector Technology	HEMT arrays			Bolometer arrays					
Center Frequency [GHz]	30	44	70	100	143	217	353	545	857
Bandwidth ($\Delta\nu/\nu$)	0.2	0.2	0.2	0.33	0.33	0.33	0.33	0.33	0.33
Angular Resolution (arcmin)	33	24	14	10	7.1	5.0	5.0	5.0	5.0
$\Delta T/T$ per pixel (Stokes I)[a]	2.0	2.7	4.7	2.5	2.2	4.8	14.7	147	6700
$\Delta T/T$ per pixel (Stokes Q & U)[a]	2.8	3.9	6.7	4.0	4.2	9.8	29.8	...	...
***ΔT/T* per deg² (Stokes *Q* & *U*)**	**1.6**	**1.6**	**1.6**	**0.7**	**0.5**	**0.8**	**2.5**		

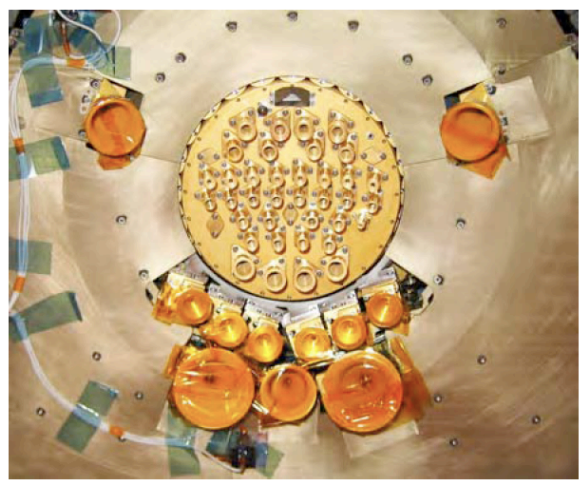
[a] Goal (μK/K, 1σ), 14 months integration, square pixels whose sides are given in the row "Angular Resolution".

Planck Bluebook

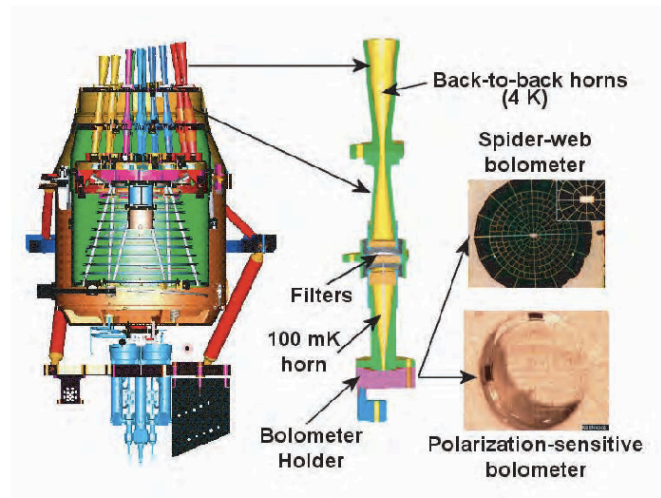
HFI will do somewhat better by end of mission



Planck Bluebook

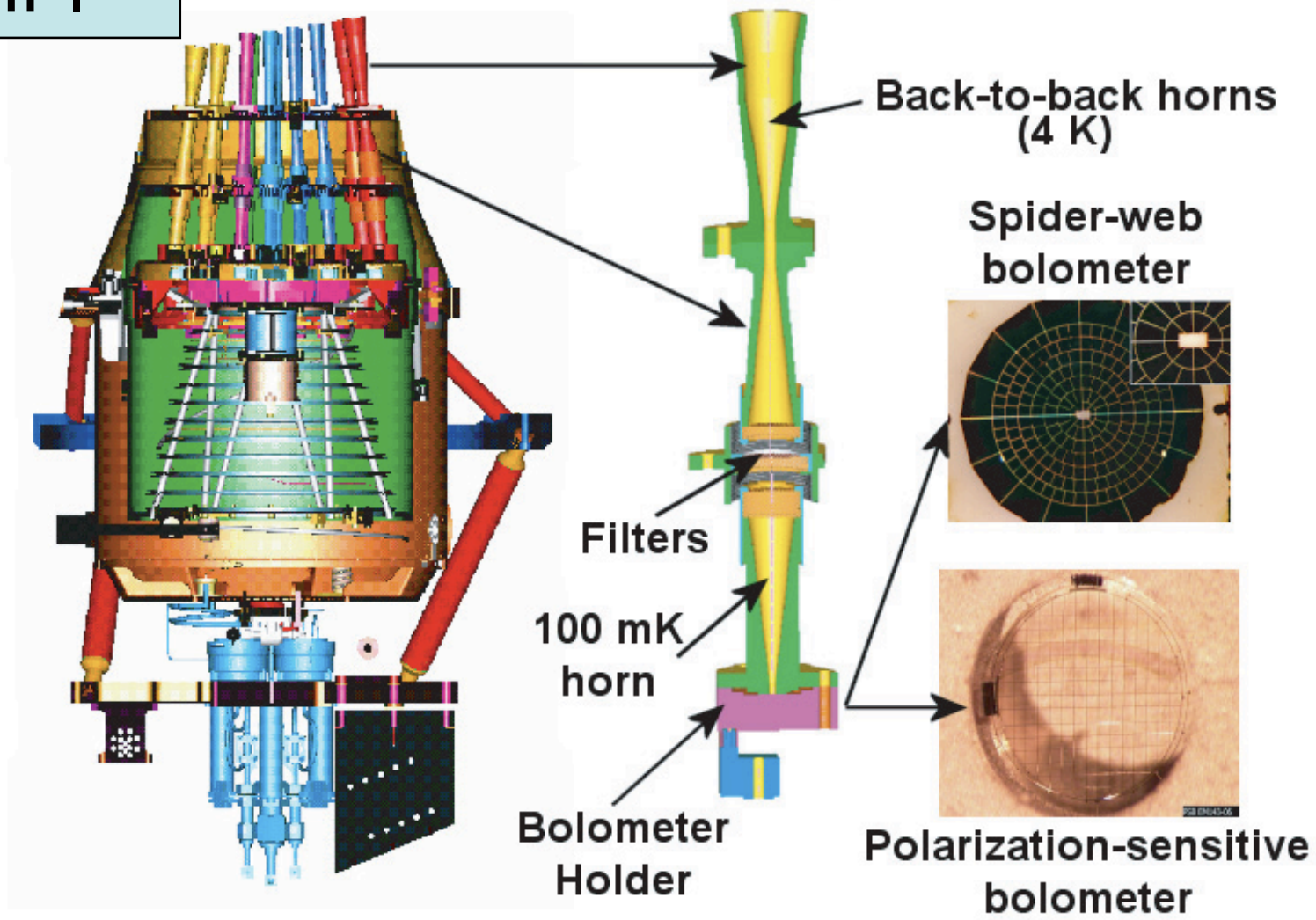


Thales/Alenia Space+ESA



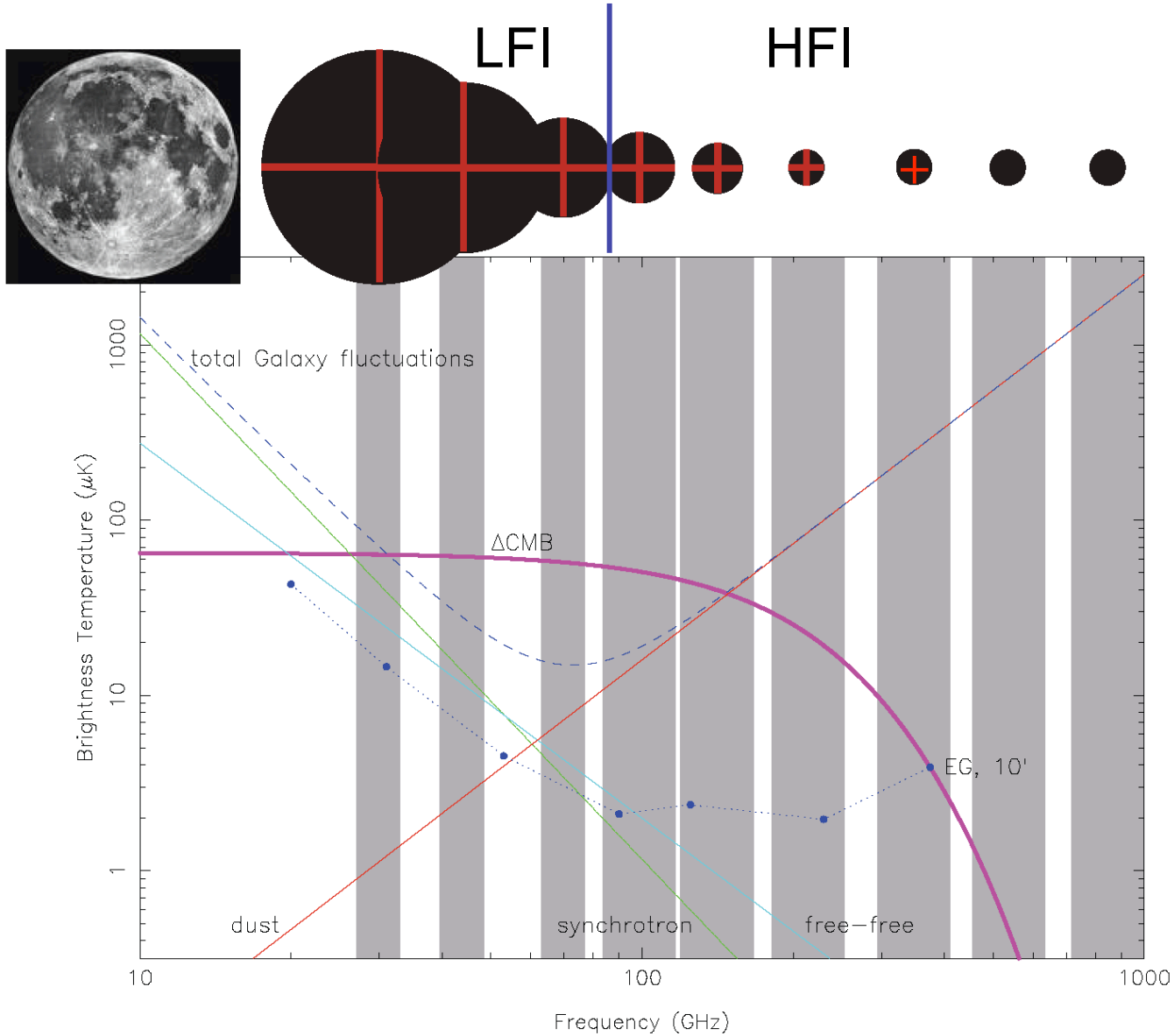
Planck Bluebook

HFI

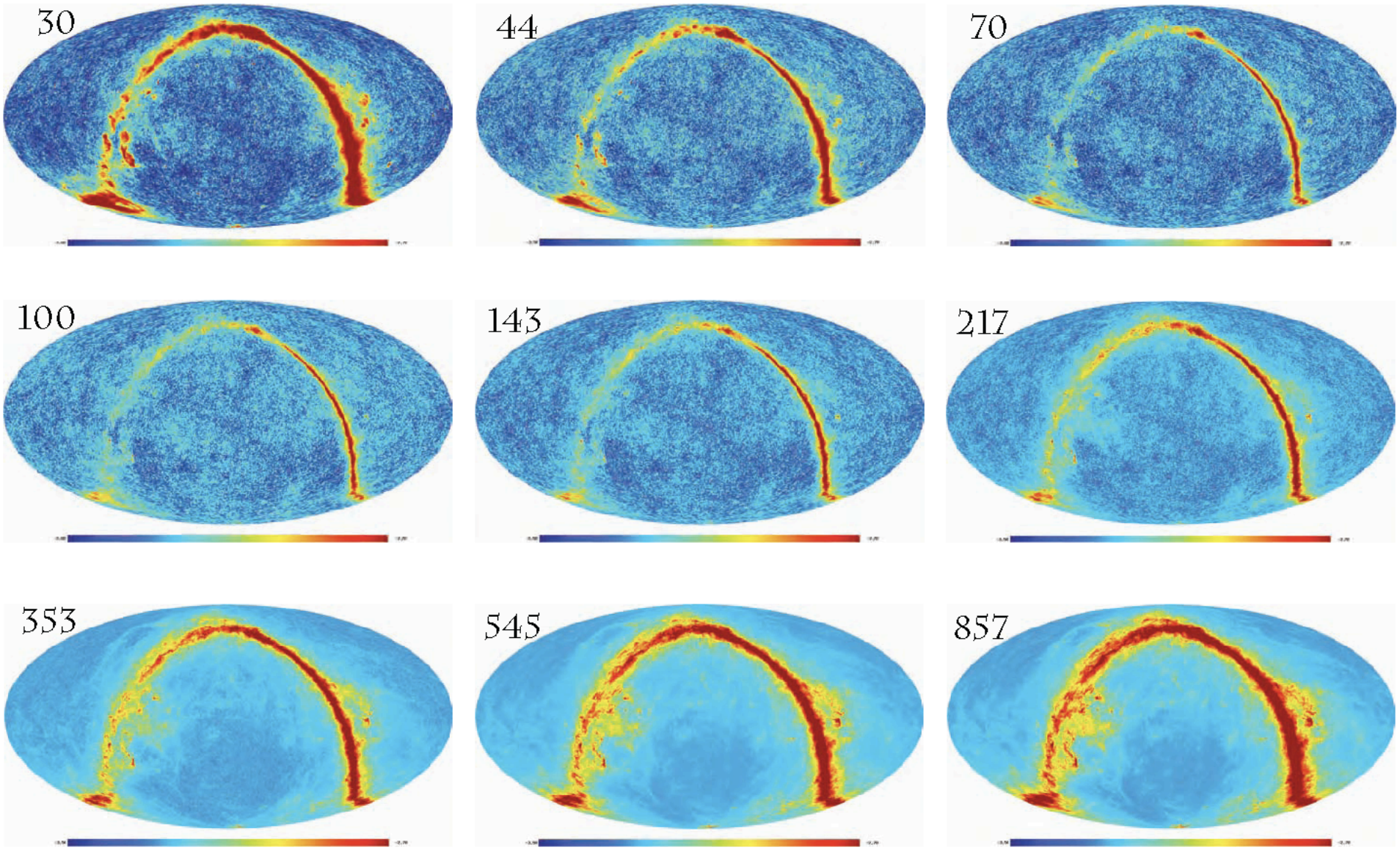


Heritage: BOOMERanG, MAXIMA, Archeops, QuAD, BICEP

Frequencies



Simulated Planck Temperature Maps



Rough Schedule

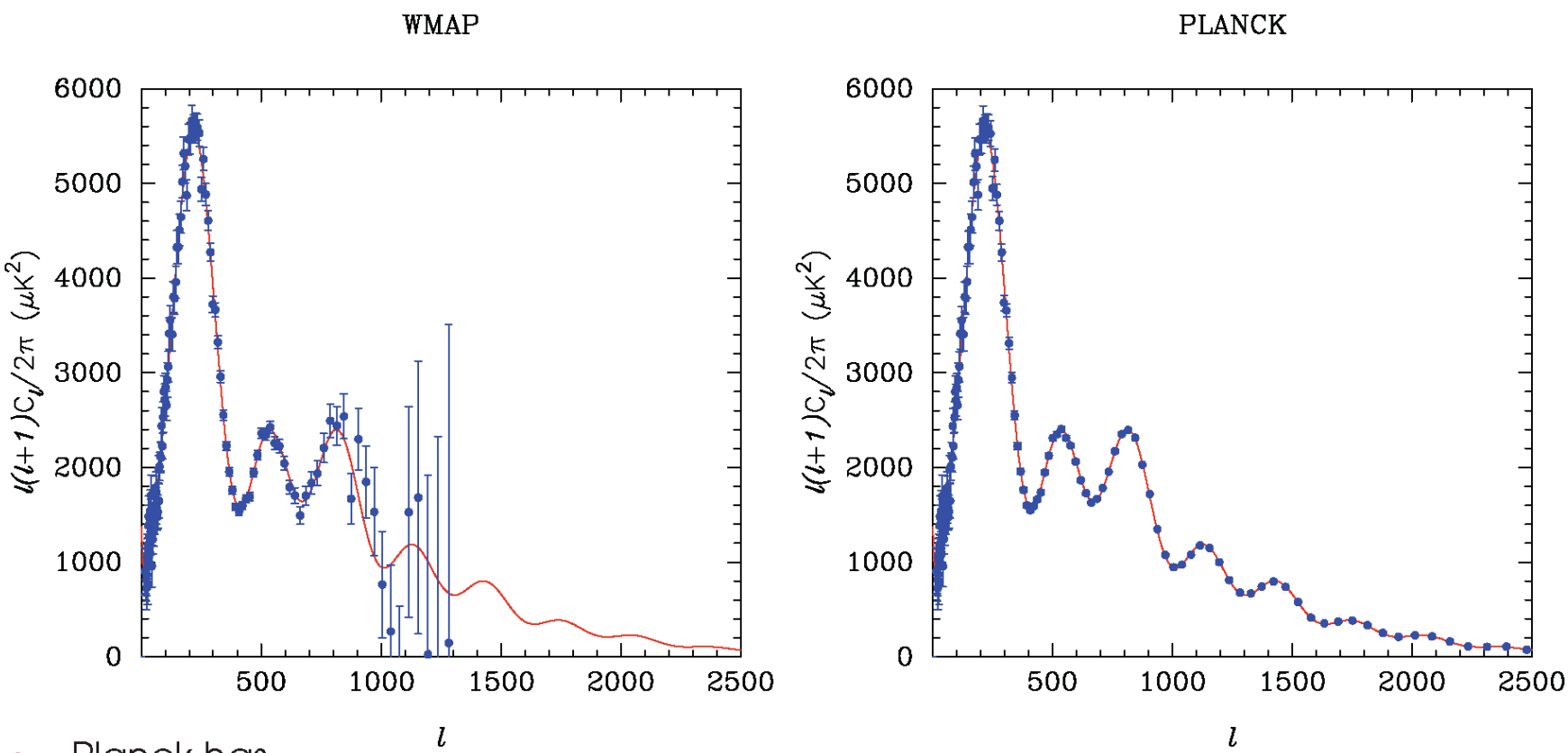
	Duration [months]	Date	
Launch	0	~~end 2008(?)~~	5/14/09
Cruise, cooldown, checkout	3	~~3/2009~~	9/09
First sky survey	6	~~9/2009~~	3/10
Second sky survey	6	~~3/2010~~	9/10
ERCSC (based on first sky survey)		~~6/2010~~	12/10
Analyze first year data	24		
Release results based on first year		~~3/2012~~	9/12
Extended mission	TBD		

Tentative Plans for First Data Release

- Based on two sky surveys
- Calibrated data
- Frequency maps
- Component maps (CMB, synchrotron, dust, etc.)
- Source catalog
- 50–100 papers
- Likelihood function

So what?

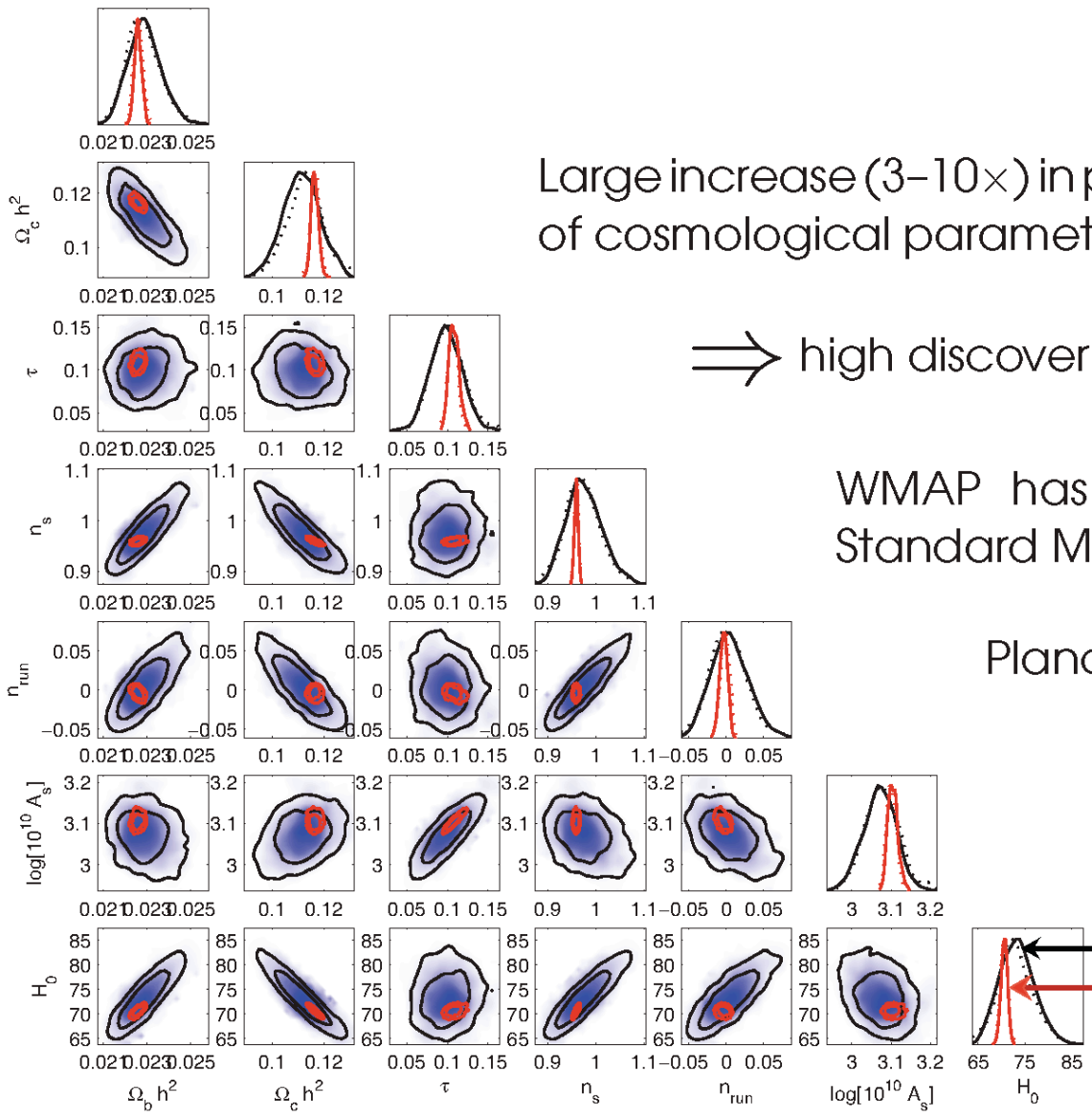
Planck and WMAP: Temperature Anisotropies



Planck Bluebook

- Planck has
  - $> 10 \times$ the sensitivity of WMAP
  - $3 \times$ the angular resolution
- Limited by cosmic variance well into the damping tail.
- WMAP measures $\sim$10% of the ℓ modes with SNR ≥ 1. Planck will get them all.

A Dramatic Advance



Large increase (3–10×) in precision of cosmological parameters

⟹ high discovery potential

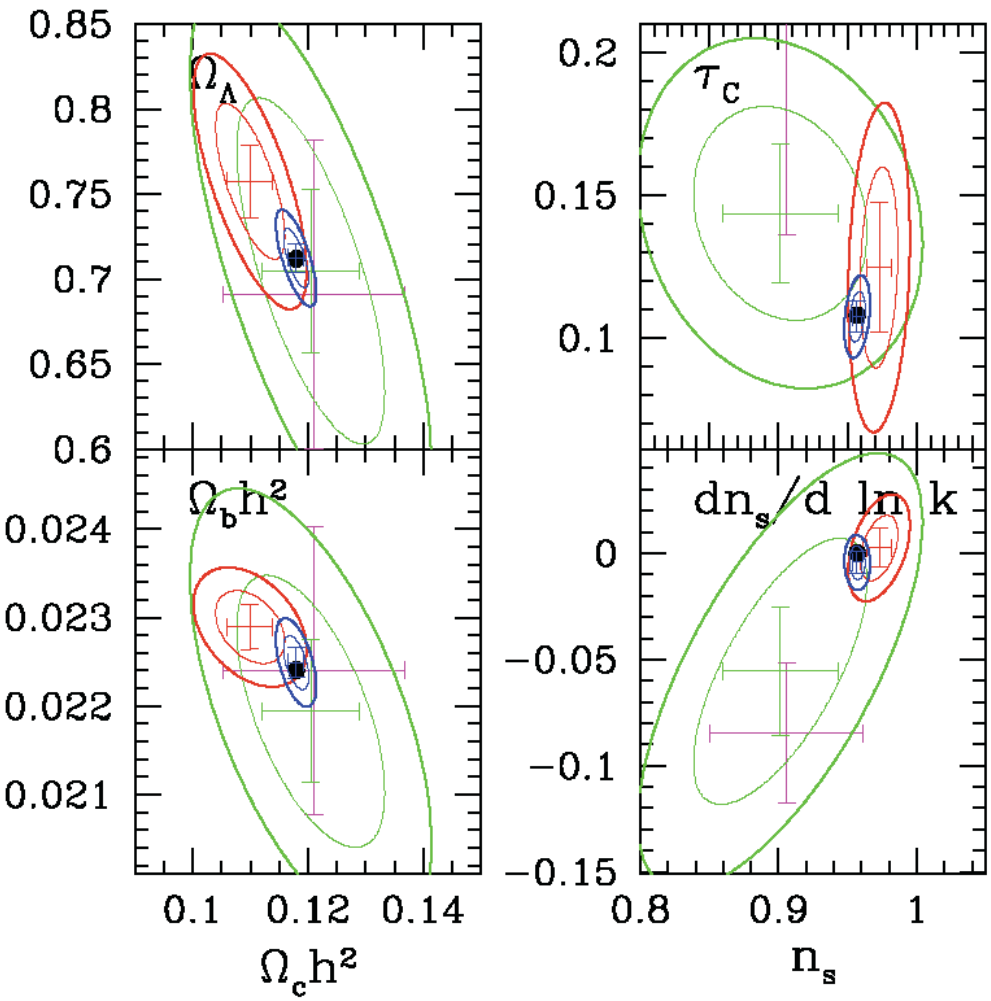
WMAP has confirmed the Standard Model

Planck will challenge it

Projected WMAP likelihood
Projected Planck likelihood
on Hubble constant

Planck Bluebook

Planck will tighten constraints on parameters in important ways

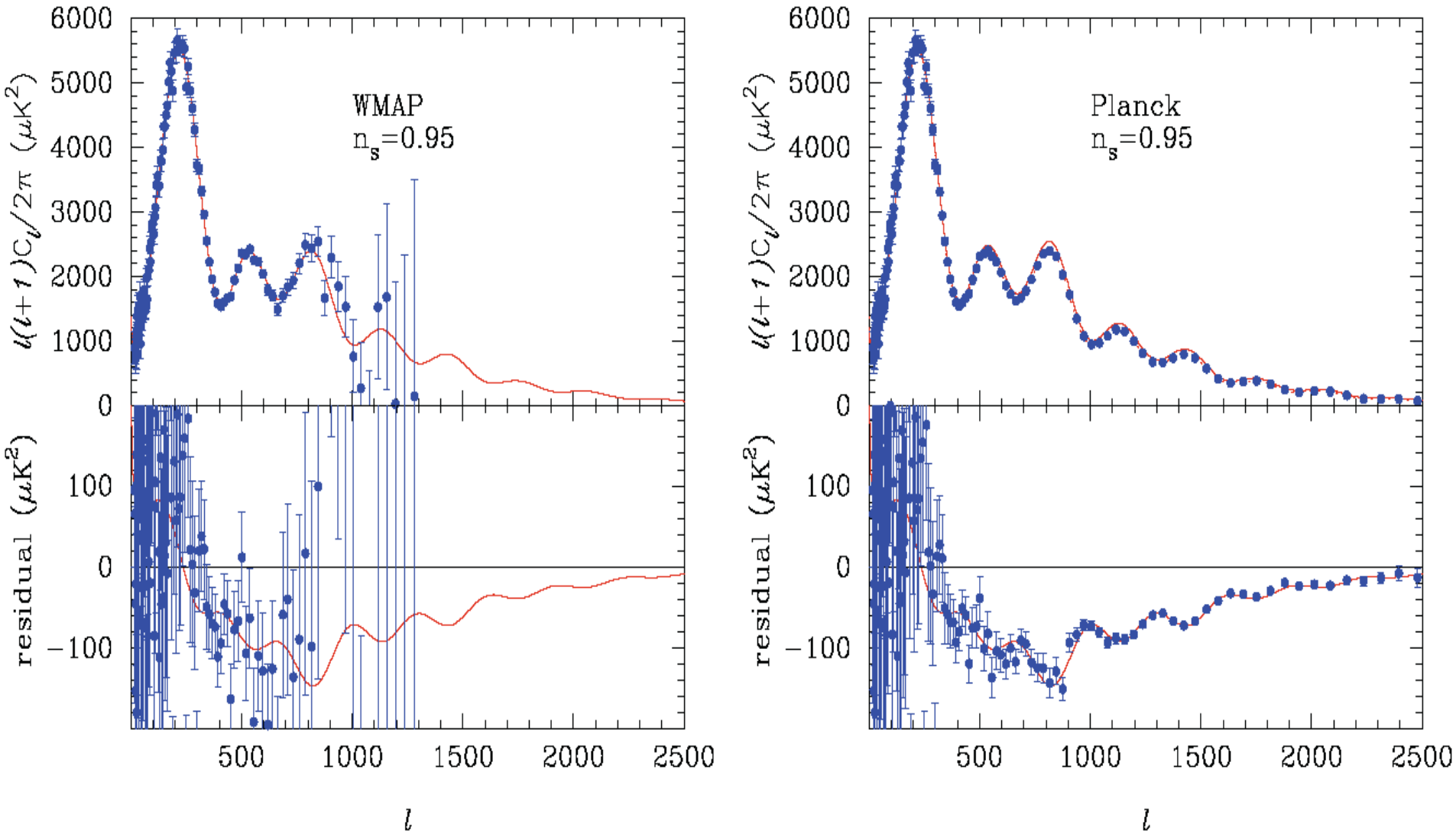


WMAP4

WMAP4 + SPT/ACT

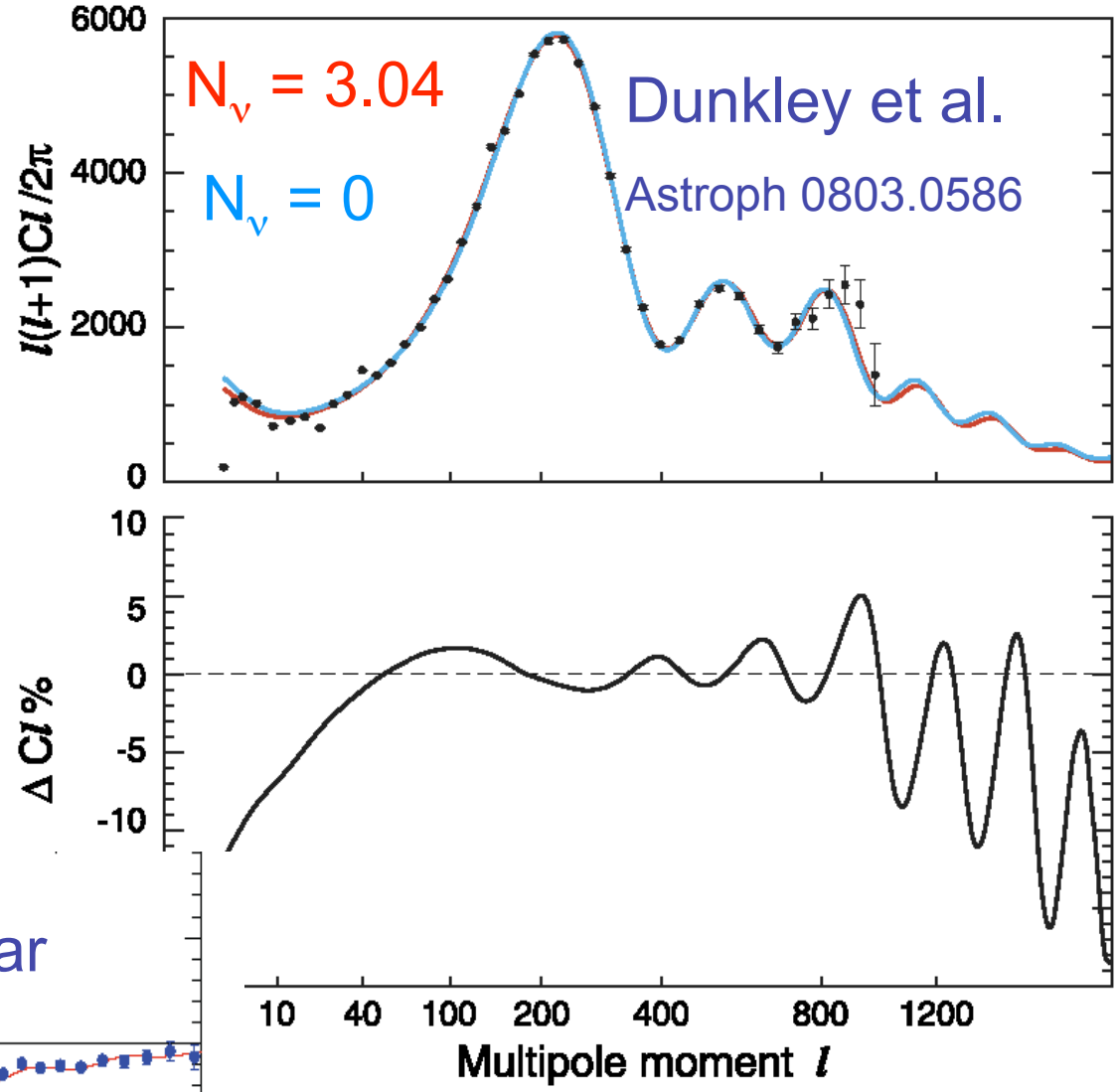
Planck 1 year

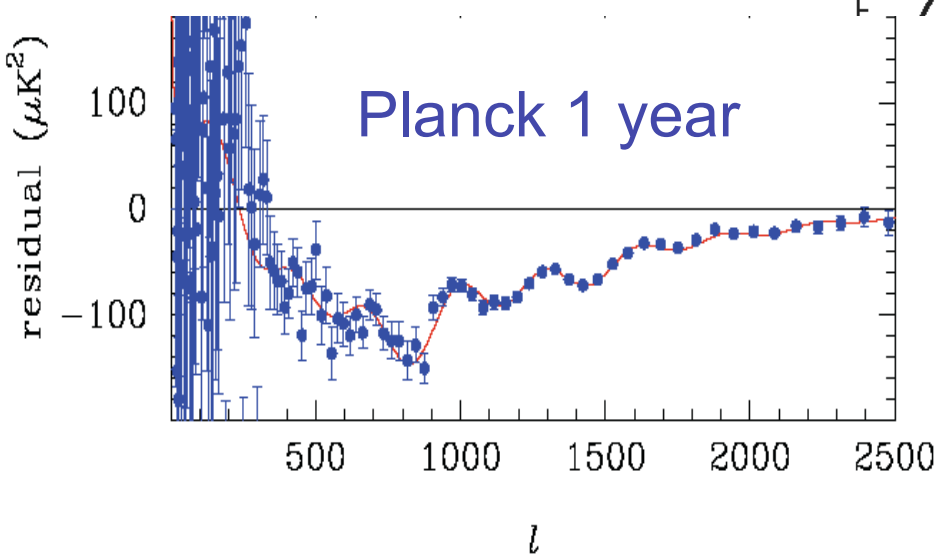
(running n_s)


WMAP
n_s=0.95
Planck
n_s=0.95
$l(l+1)C_l/2\pi$ (μK^2)
residual (μK^2)
l
6000
5000
4000
3000
2000
1000
0
100
0
−100
500
1000
1500
2000
2500

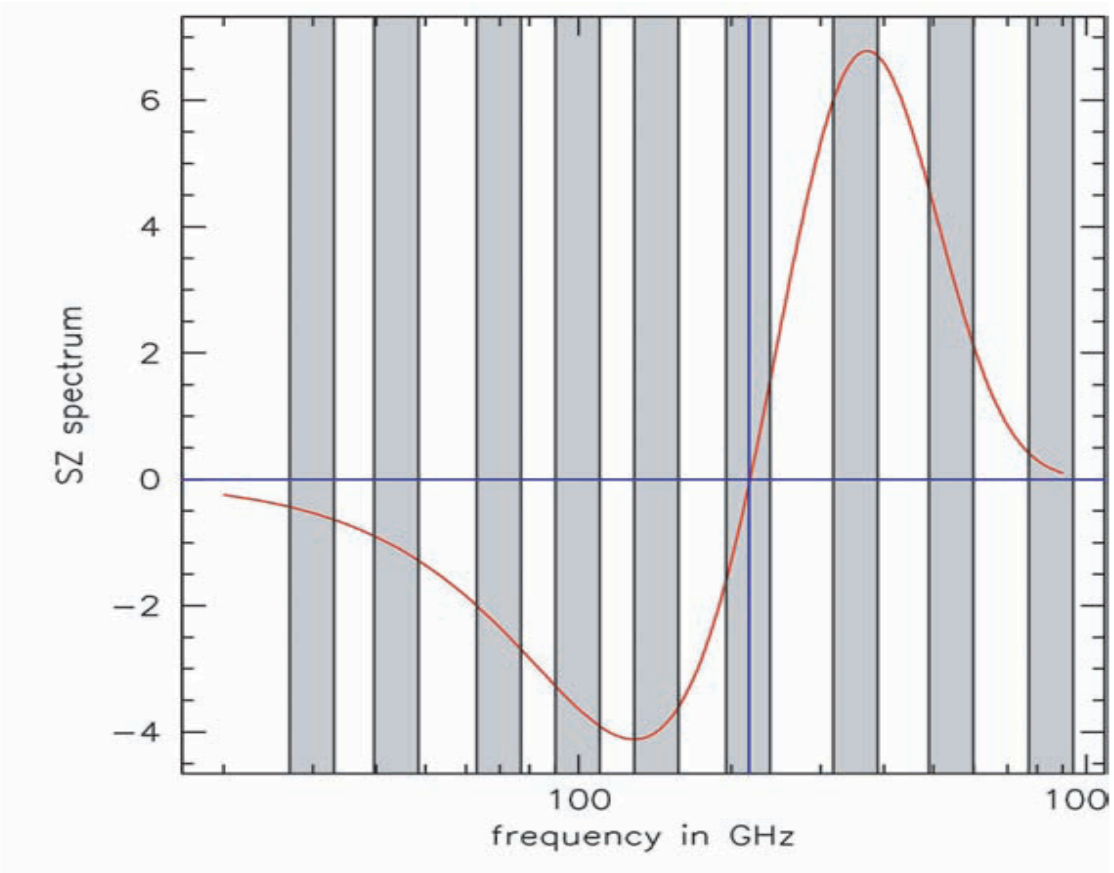
Lots of physics at

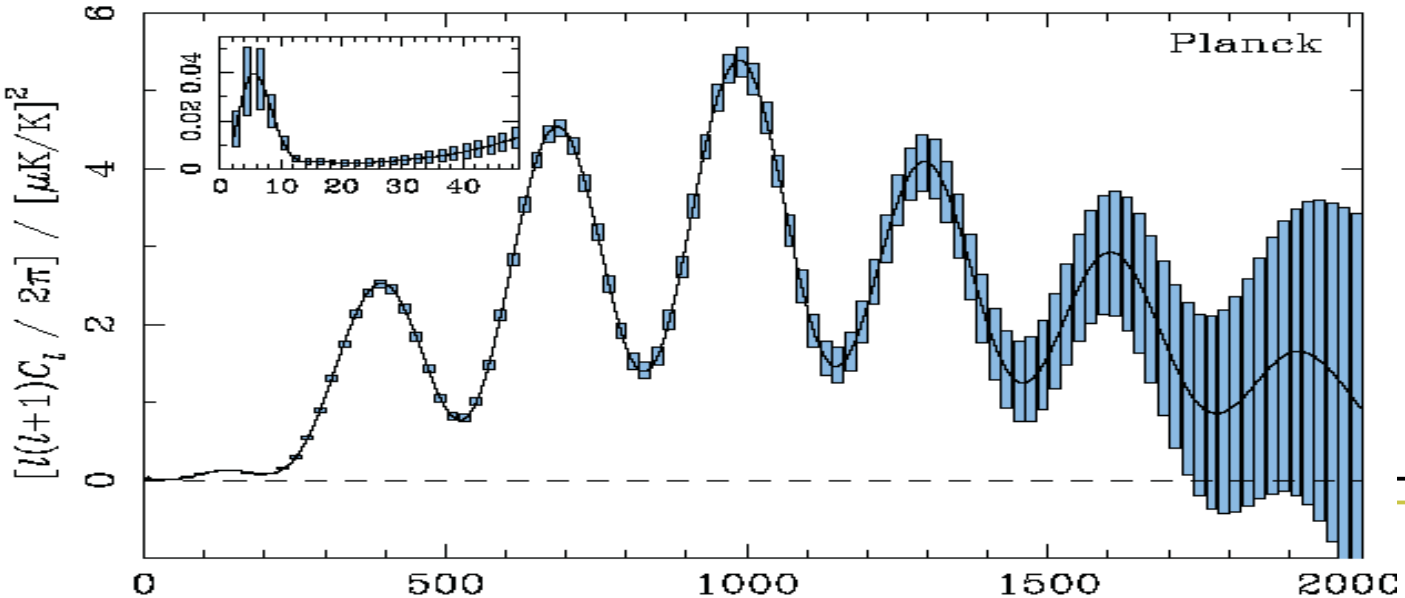
$\ell \sim 500 \rightarrow 2000$!



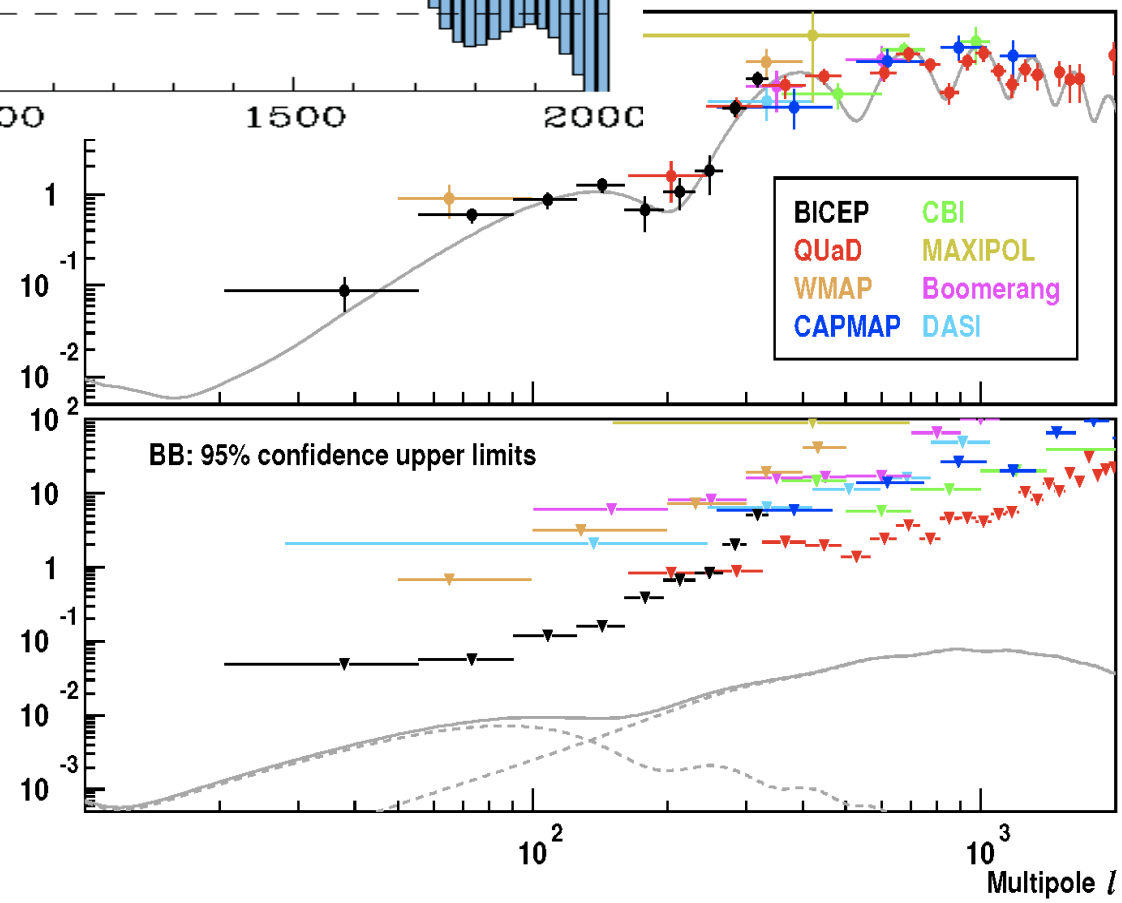


It will be important (and interesting) to separate out the SZ contribution to the power spectrum (and Planck will do this well)

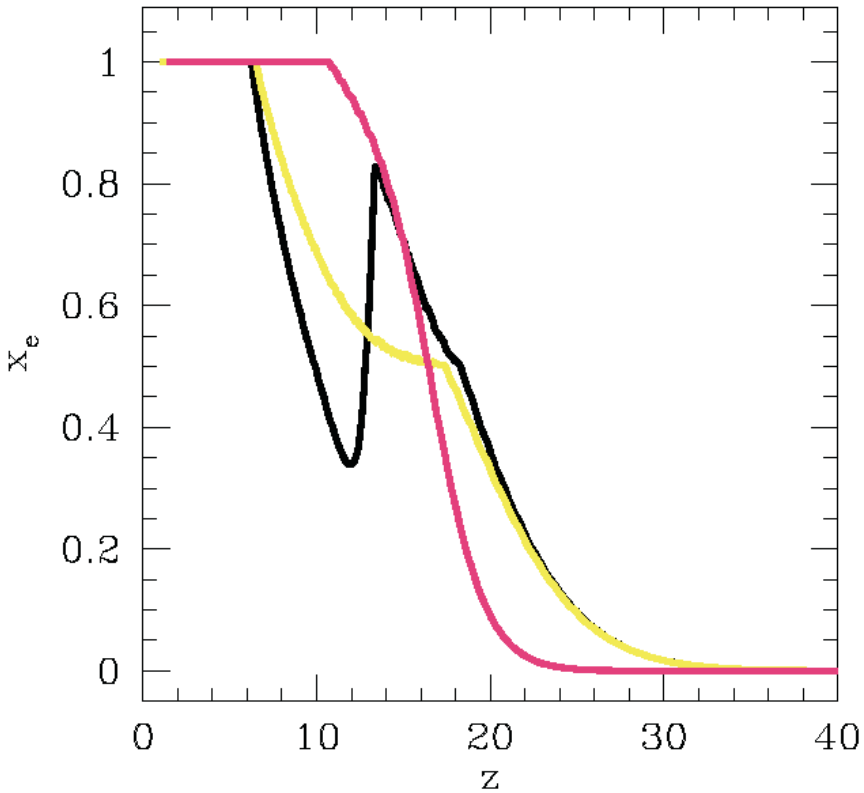


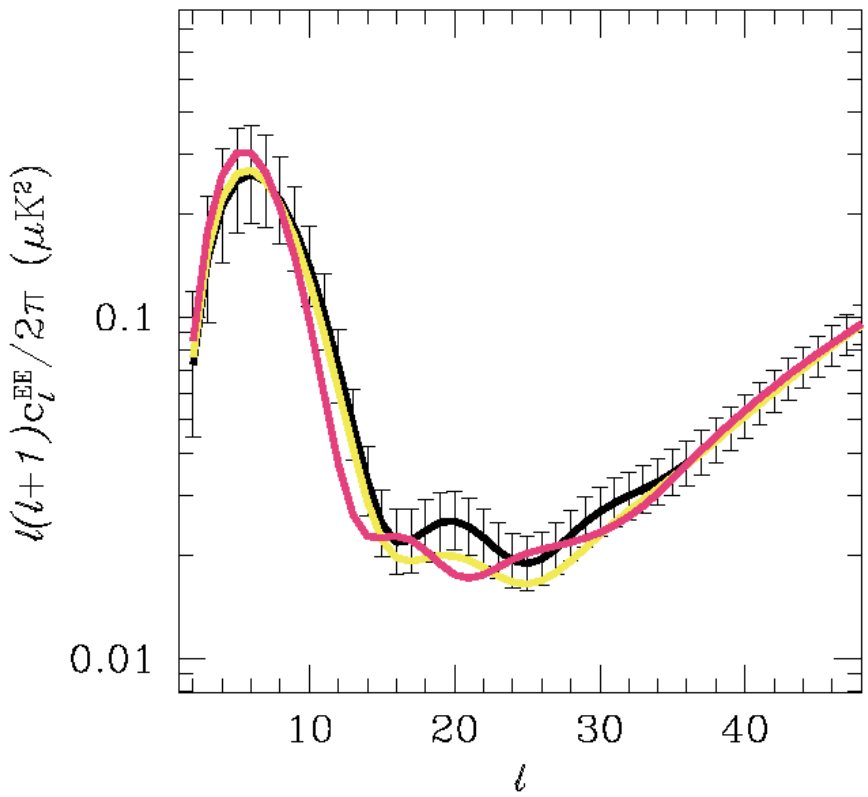


Planck will measure EE with high precision from $\ell \sim 40 \rightarrow 1200$



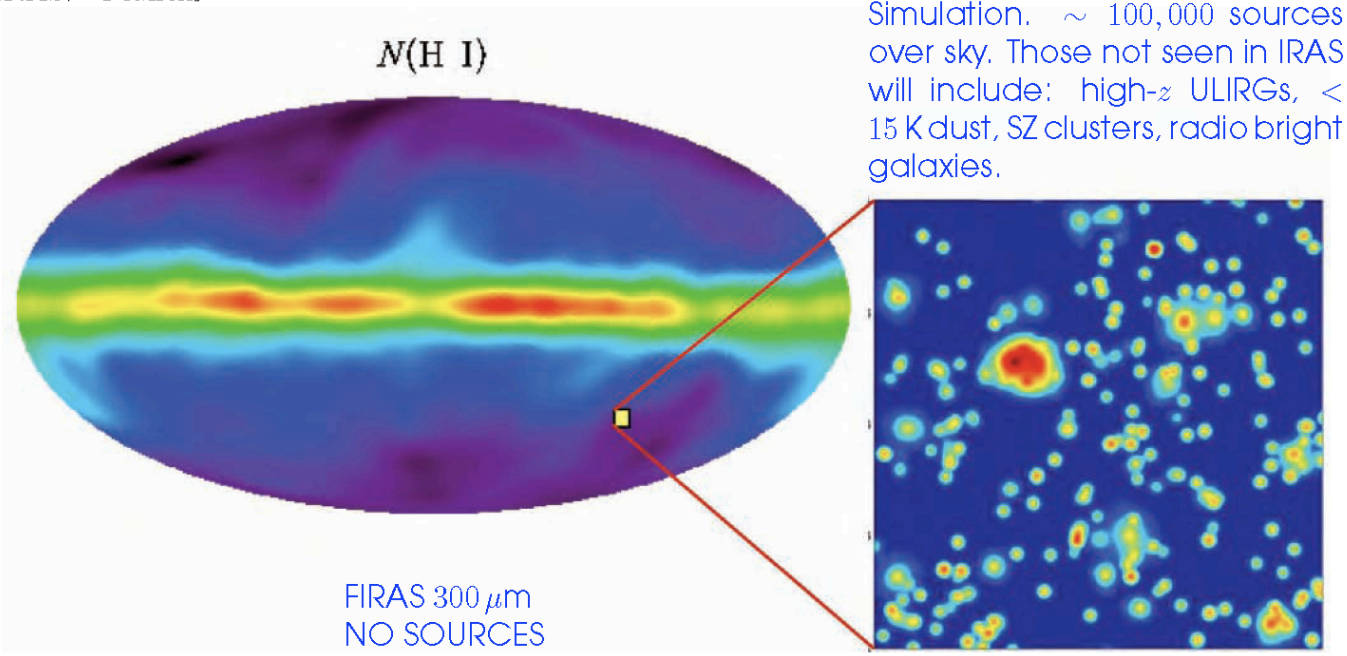
One might learn about reionization from details of low l EE, but not from Planck……





Non-CMB Science Example: Discrete Sources

- Planck will measure the entire sky at 9 frequencies from 30 to 857 GHz
- At frequencies above 100 GHz, Planck will be the only all-sky survey since FIRAS
- Planck sensitivity to compact sources is $> 10^4$ times better than FIRAS!!
  - FIRAS: 7° resolution, NO discrete sources
  - Planck: 5′ resolution at 350, 550, 850, and 1400 μm; 7′ at 2 mm; 10′ at 3 mm
  - $[\theta_{\rm FIRAS}/\theta_{\rm Planck}]^2 > 7000$



Simulation. $\sim 100,000$ sources over sky. Those not seen in IRAS will include: high-z ULIRGs, $<$ 15 K dust, SZ clusters, radio bright galaxies.

Andrew Lange

The Early Release Compact Source Catalog

- To enable follow-up observations with, e.g., Herschel, a catalog of bright sources will be released about 19 months after launch, based on the first full sky survey.

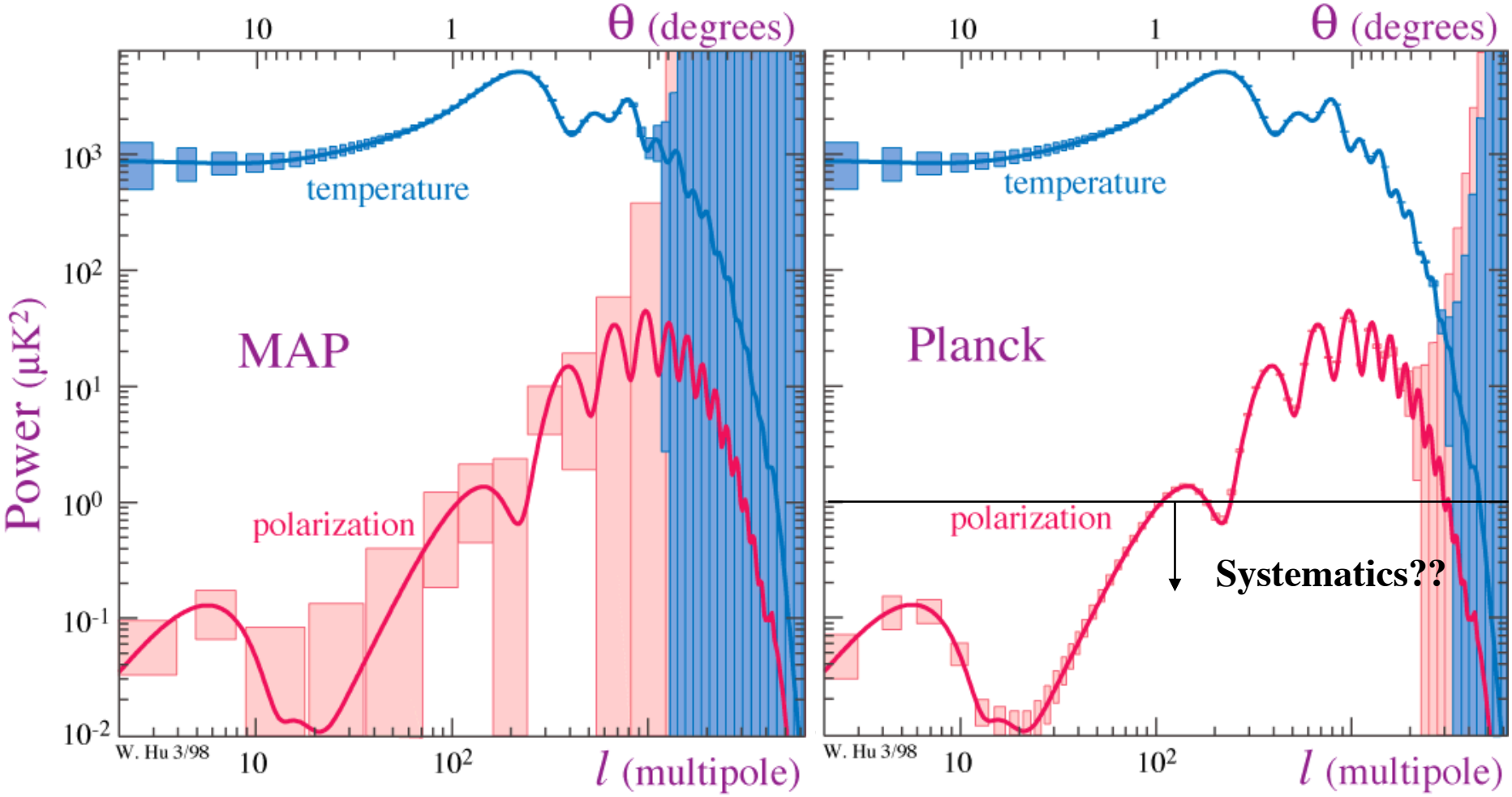
Channel	1	2	3	4	5	6	7	8	9
Freq (GHz)	30	44	70	100	143	217	353	545	857
Wavelength (m)	10000	6818	4286	3000	2098	1382	850	550	350
Beam (')	33	24	14	9.5	7.1	5	5	5	5
F(mJy)/[dT/T*10^3]	6818	7557	6040	5007	4461	2833	1761	346	8.97
Noise dT/T*10^6	2.0	2.7	4.7	2.5	2.2	4.8	14.7	147	6700
Noise (mJy)	13	19	25	9	13	9	20	46	52
Confusion (mJy)					4	6	17	43	91
CMB noise (mJy)	78	80	61	64	56	31	16	3	
Dominant noise	CMB	CMB	CMB	CMB	CMB	CMB	Noise	Noise	Confusion
10-sigma ERCSC goal (mJy)	790	820	660	650	580	330	310	630	1048

Bill Reach

Nature 458 April 16, 2009

Princeton, March 2003…..

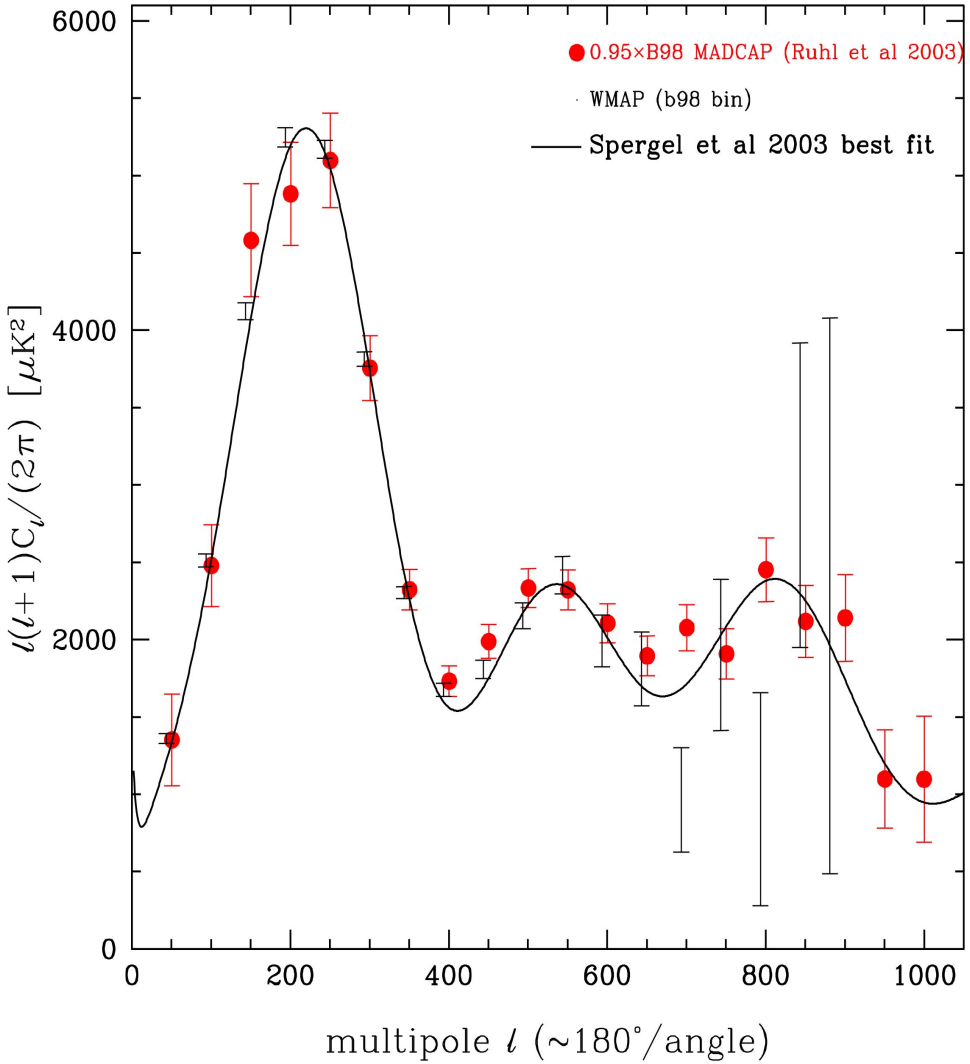
Polarization sensitivity does not a polarimeter make …



Minneapolis, March 2003…..

Does a satellite make sense?

(yes, much like going to the dentist makes sense…)



+:

Stable, clean environment

Long integration time

Entire EM band available

-:

5 - 10 year old technology

$$$ (but still << mOIF)

CDRs, ICDs, WPAs

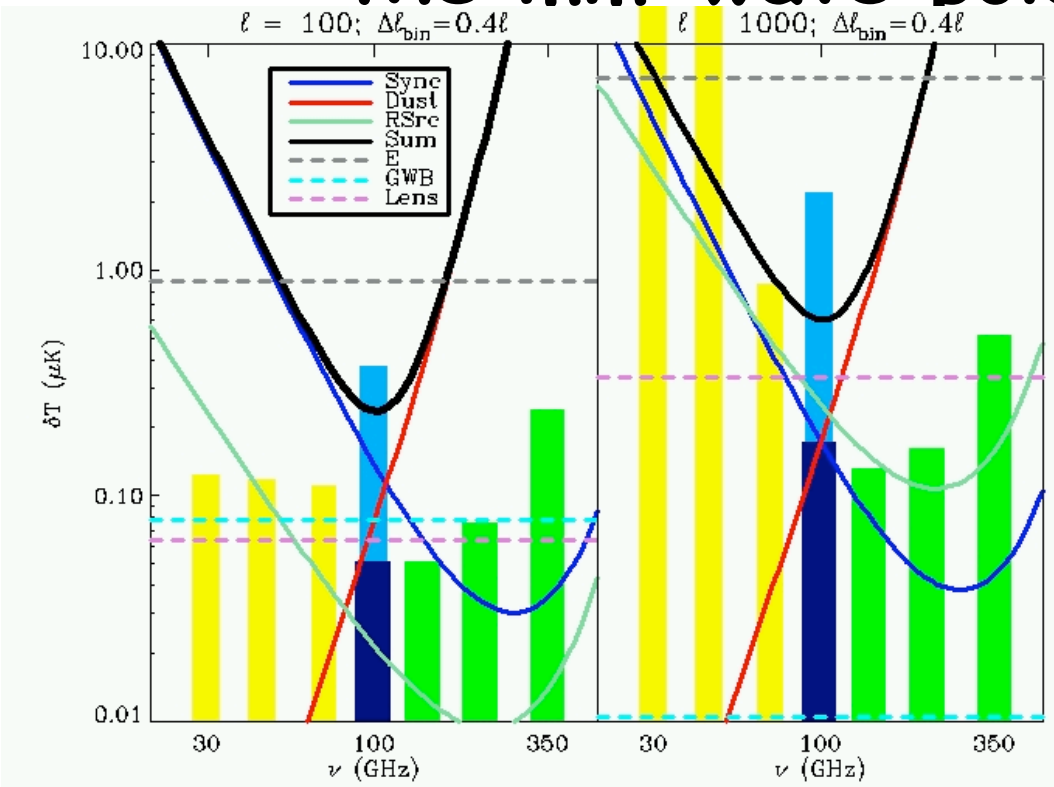
It can blow up [P(>5%)]

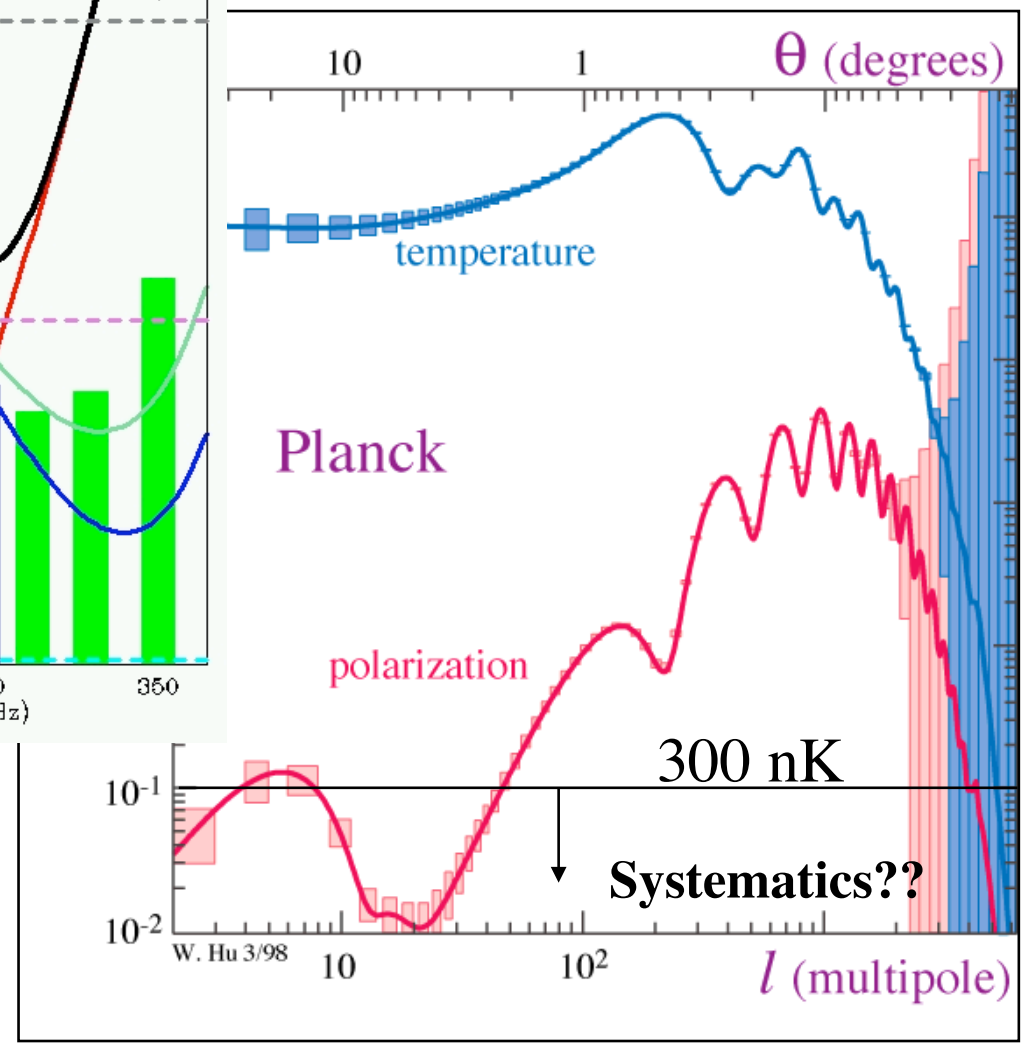
You will get old

You might get beat ….

Minneapolis, March 2003…..

Planck will revolutionize our understanding of the mm-wave polarized sky





WMAP 4 year

LFI 2 year

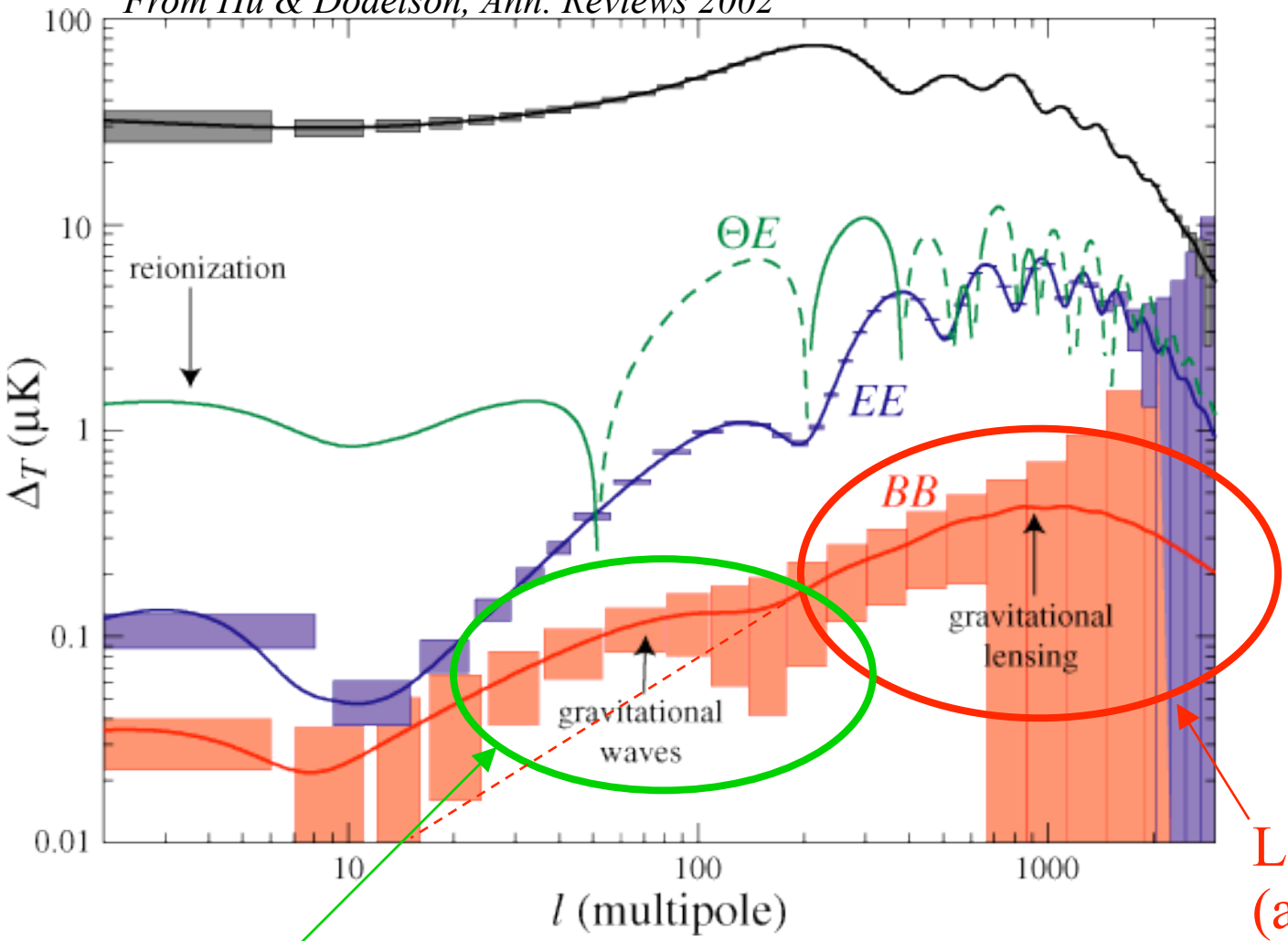
HFI 1 year

Proposed 100 GHz polarized HFI channel, 1 year

Minneapolis, March 2003…..

Planck could detect evidence for the GWB:

From Hu & Dodelson, Ann. Reviews 2002



All sky

6 (or 7) polarized channels from 30 to 350 GHz

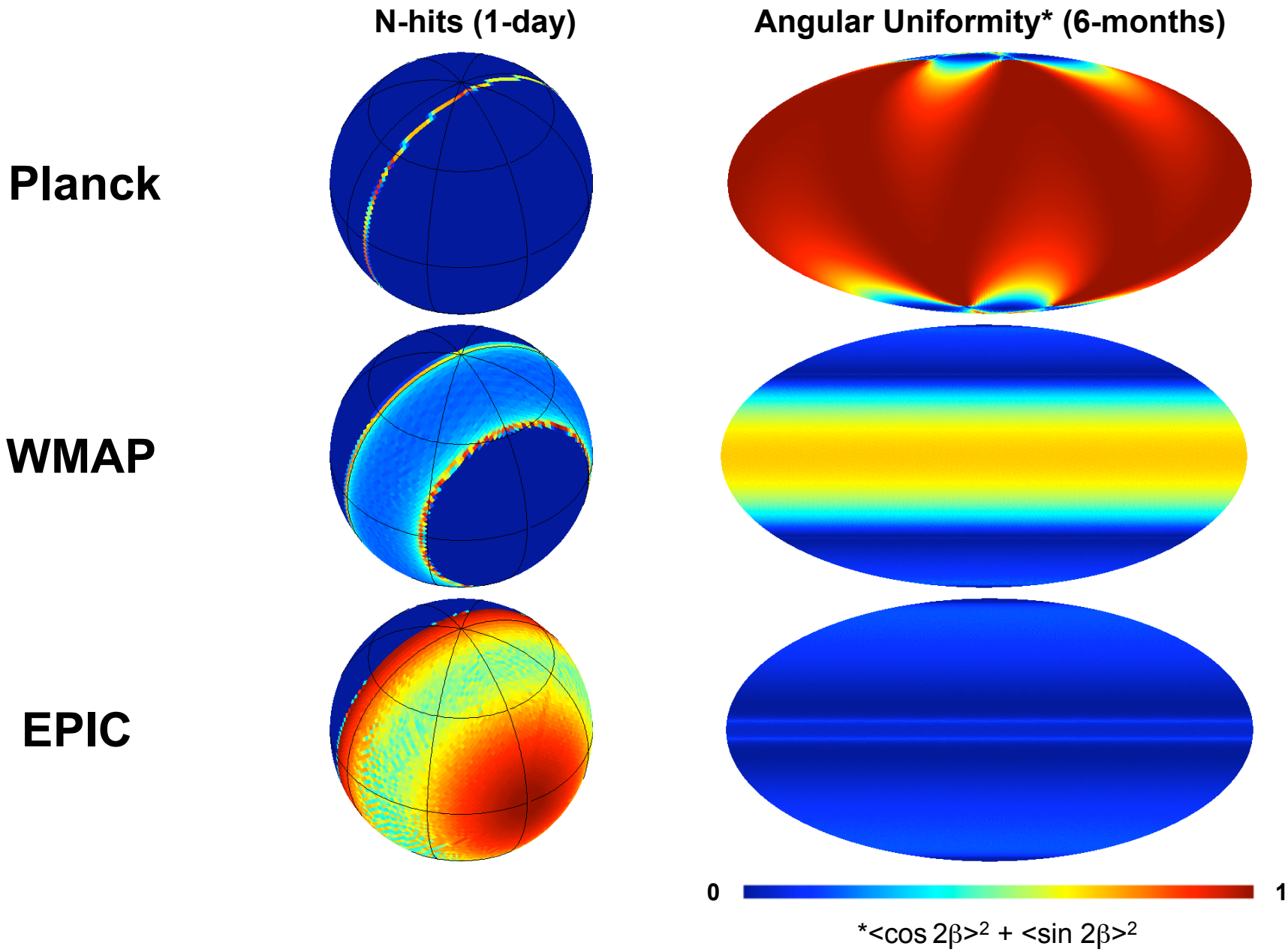
Angular resolution sufficient to detect lensing mode.

Lensing B-modes (a foreground)

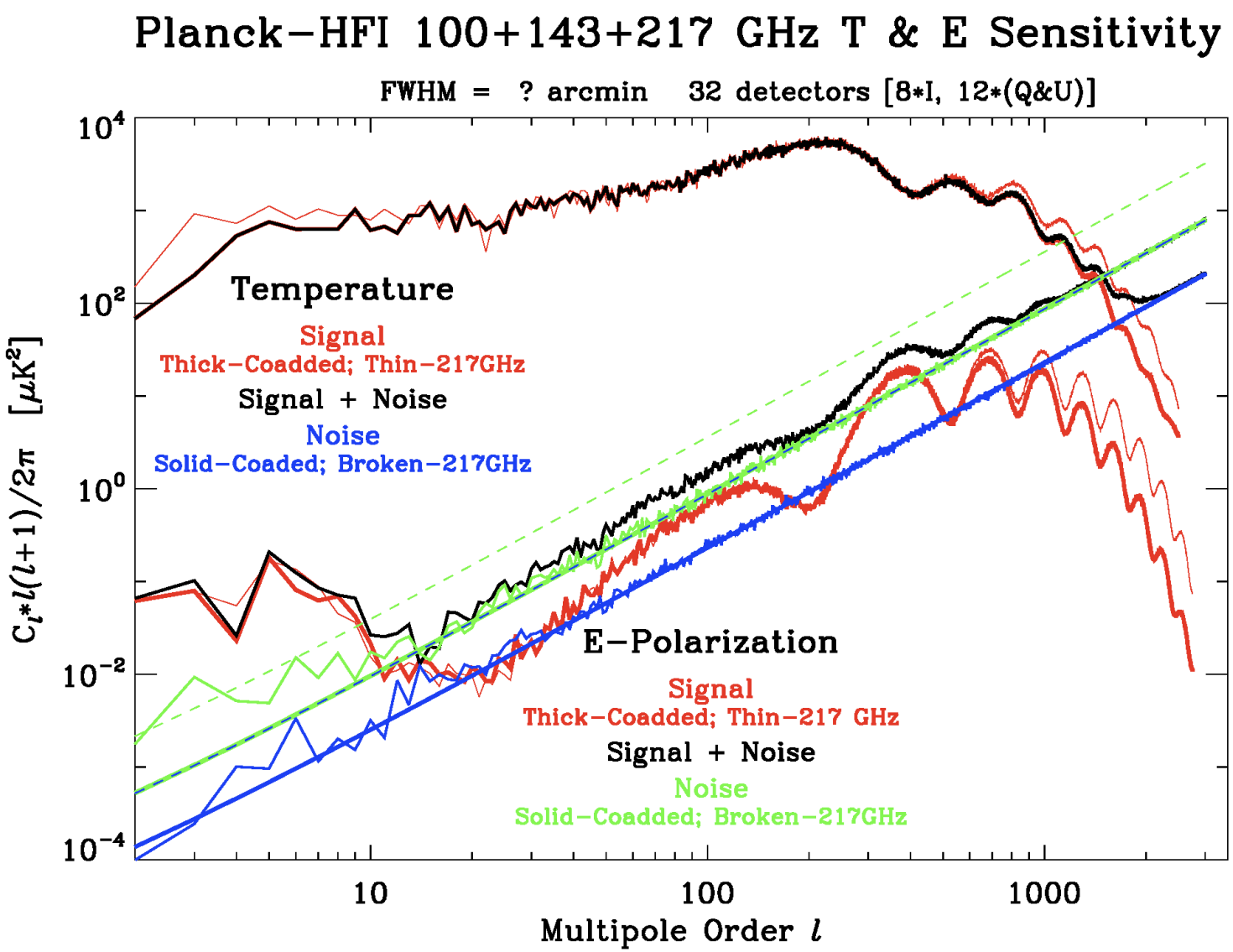
Primordial B-modes, fingerprint of Inflation. (Shown for T/S = 0.1, a high value??)

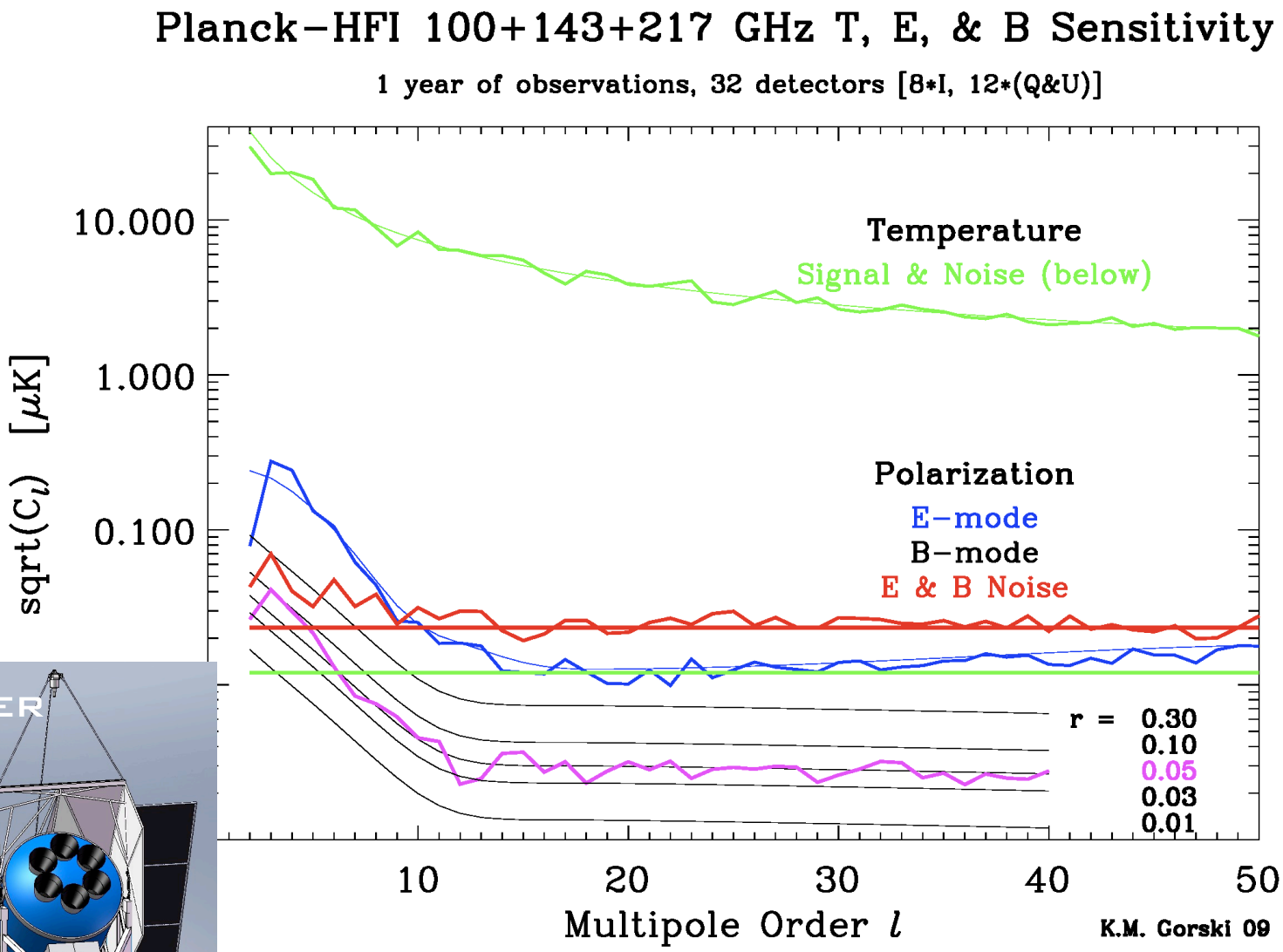
The advantages of space…

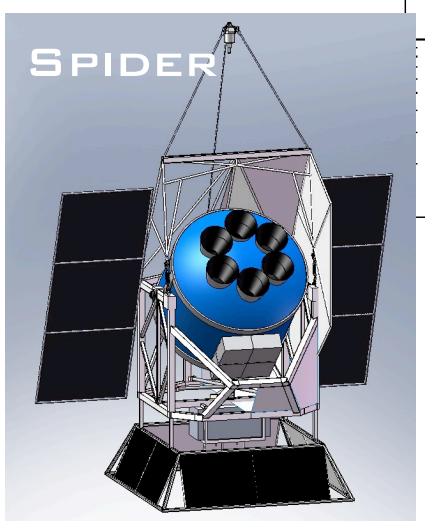
Ideal Scan Strategy for All-Sky Polarization Measurement



“You don’t observe the CMB with the scan strategy you wish you had - you observe the CMB with the scan strategy you have.”


Planck−HFI 100+143+217 GHz T & E Sensitivity
FWHM = ? arcmin 32 detectors [8*I, 12*(Q&U)]
Temperature
Signal
Thick−Coadded; Thin−217GHz
Signal + Noise
Noise
Solid−Coaded; Broken−217GHz
E−Polarization
Signal
Thick−Coadded; Thin−217 GHz
Signal + Noise
Noise
Solid−Coadded; Broken−217GHz
$C_l*l(l+1)/2\pi$ [μK^2]
Multipole Order l
10^4
10^2
10^0
10^{-2}
10^{-4}
10
100
1000


Planck−HFI 100+143+217 GHz T, E, & B Sensitivity
1 year of observations, 32 detectors [8*I, 12*(Q&U)]
Temperature
Signal & Noise (below)
Polarization
E−mode
B−mode
E & B Noise
r = 0.30
0.10
0.05
0.03
0.01
10.000
1.000
0.100
sqrt(C_l) [μK]
10
20
30
40
50
Multipole Order l
K.M. Gorski 09


SPIDER

Conclusions

- Planck *will not* detect a cosmological B-mode
- Planck *will* test Inflation via:
  - a high-precision measurement of n_s
  - high sensitivity to non-guassianity
- **A sub-orbital experiment designed to probe CMB pol at l < 20 is important**
  - Reionization history (a real cosmological signal!)
  - Understand foregrounds for EPIC
  - Search for the elusive B-mode….