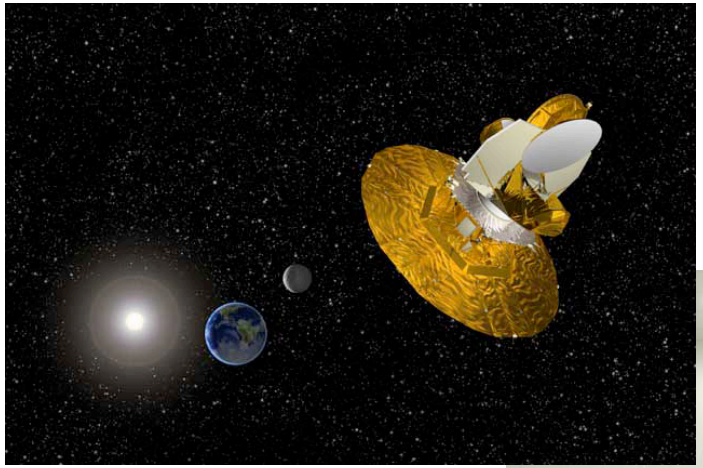
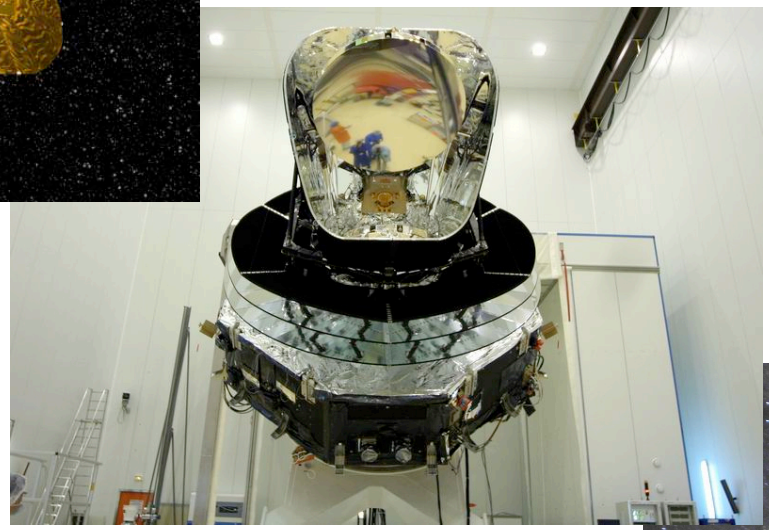
WMAP and Planck (and SPT)

Lloyd Knox

UC Davis



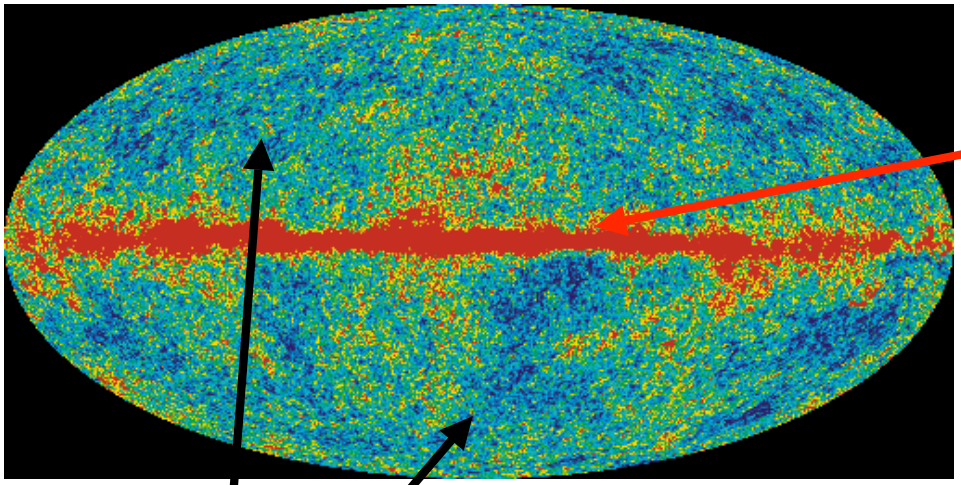
Review of results from WMAP



What to expect from Planck*

Recent results from SPT*

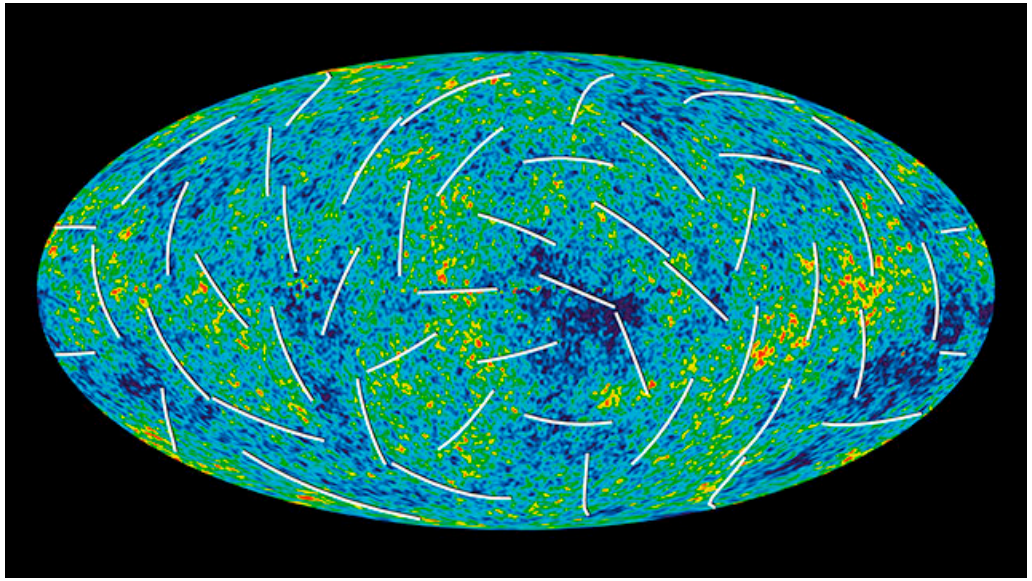
WMAP maps



Galactic emission (synchrotron, free-free and thermal emission from interstellar dust)

Full-sky 94 GHz intensity map

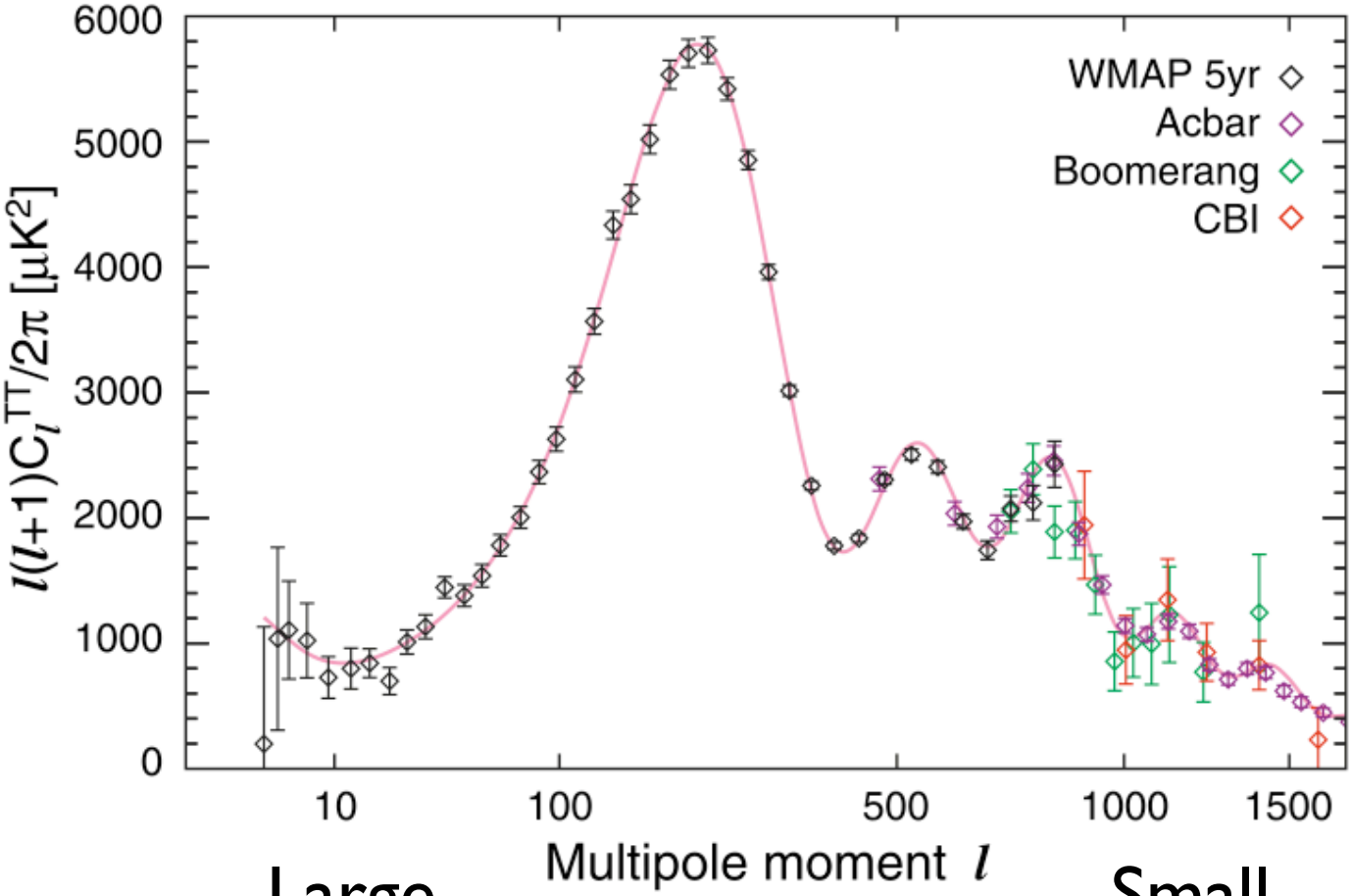
Away from galactic plane the signal is mostly due to density fluctuations on the last-scattering surface



Polarization map over CMB map

Nolta et al. (2009)

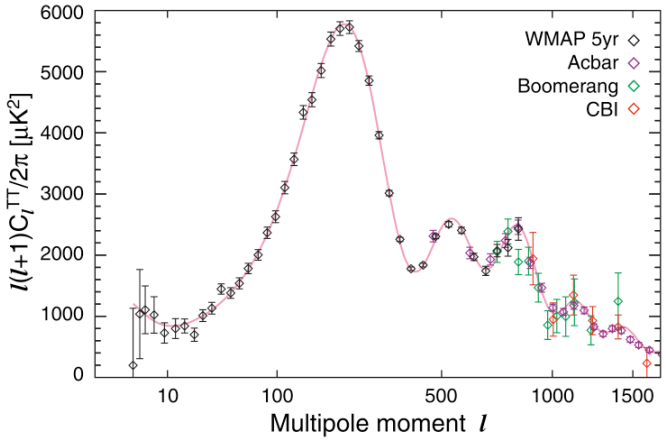
WMAP Power Spectra

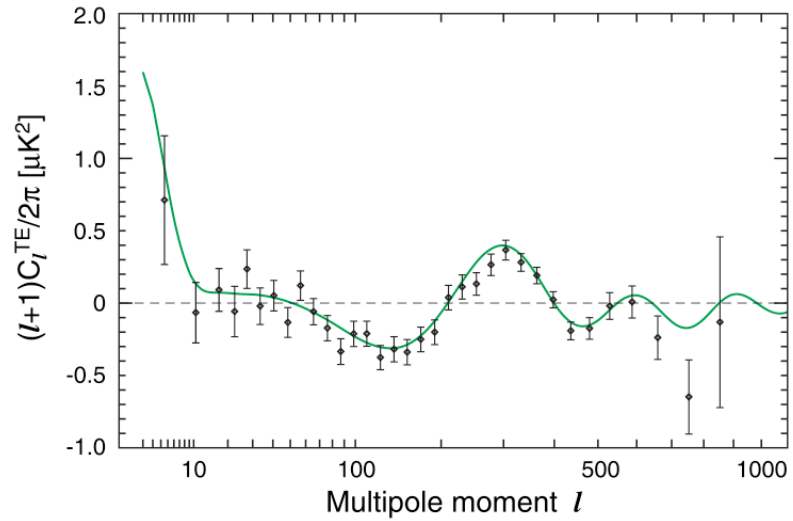


Large angular scales

Small angular scales

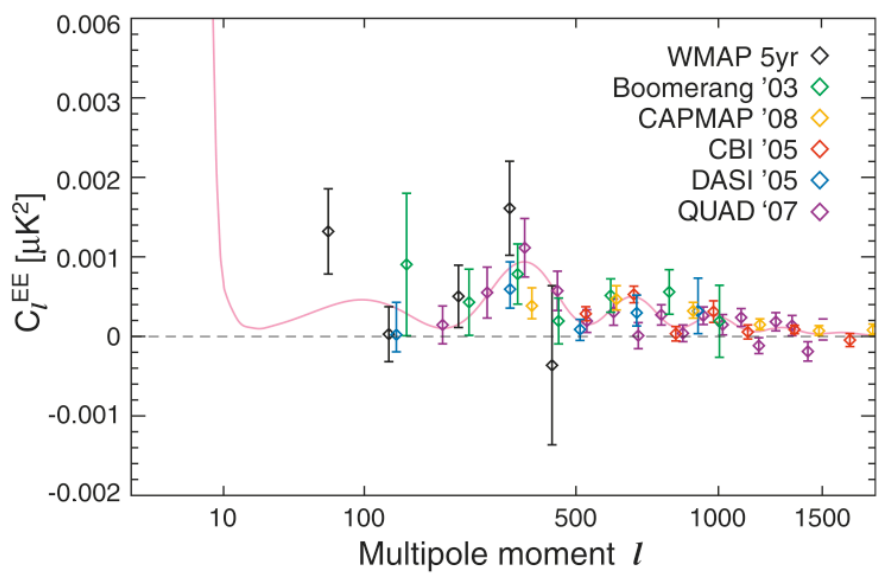
WMAP Power Spectra





Temperature-polarization Cross-power

`E-mode' polarization power



All fit by a simple model

The Standard (minimal) Cosmological Model

Geometry: flat

Dark matter: cold

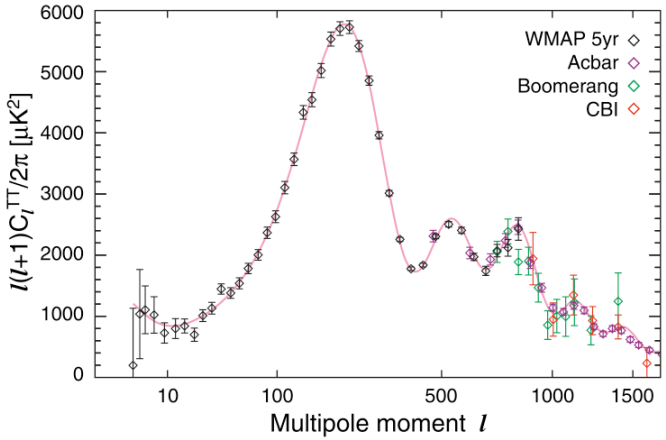
Dark energy: cosmological constant

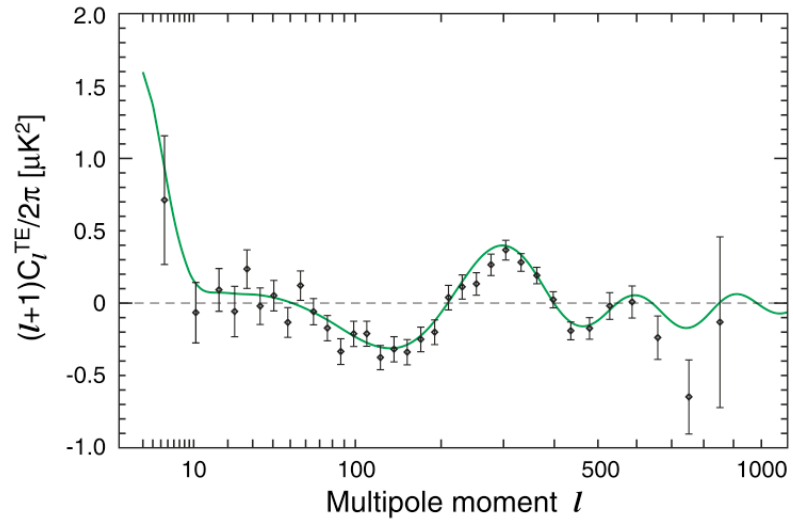
Initial perturbations: adiabatic and Gaussian with a nearly scale-invariant power-law power spectrum

To model CMB well need at least six parameters:

baryon density today ($\Omega_b h^2$), total matter density today ($\Omega_m h^2$), Cosmological Constant (Ω_Λ), optical depth to Thomson scattering (τ), initial power spectrum amplitude and spectral index (A, n_S).

WMAP Power Spectra





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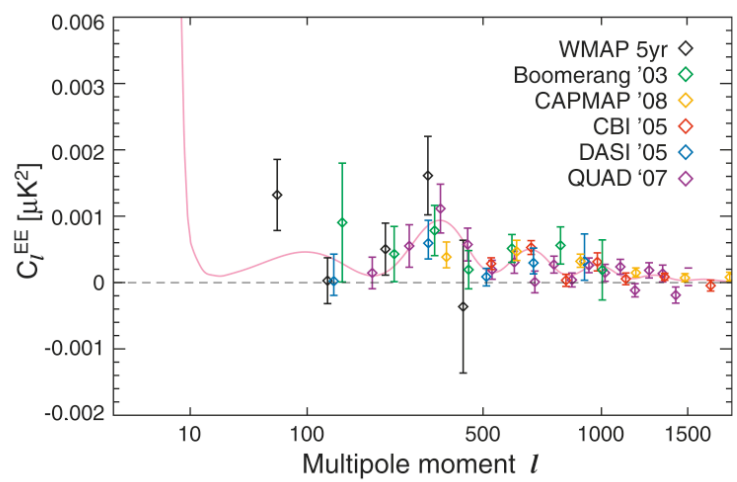
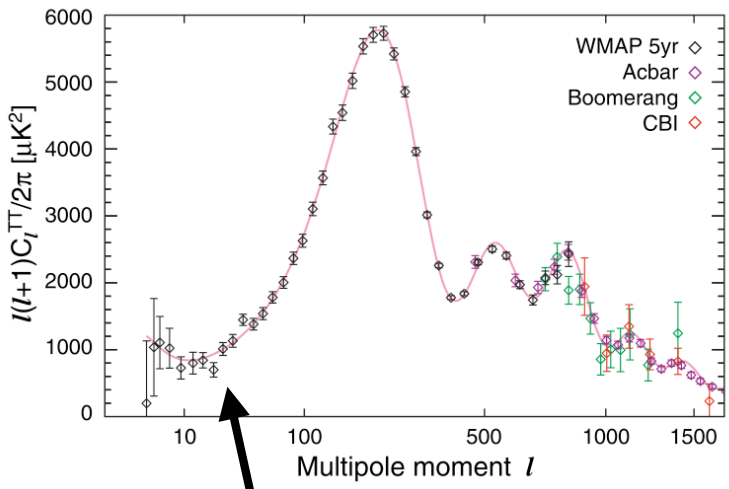


The simple model works very well.

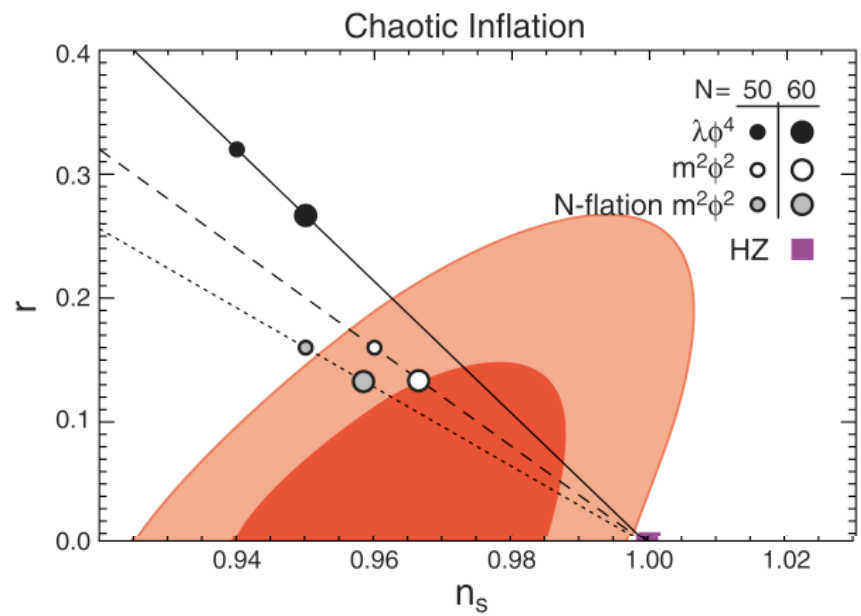
Extensions to the Minimal Model

- Gravity waves from inflation
- Non-zero mean curvature
- Massive neutrinos
- Non-constant dark energy
- Isocurvature modes
- Non-Gaussianity
- …

Gravity Waves from Inflation



Gravity waves contribute to Temperature power spectrum only at large angular scales, distorting the shape.



r parameterizes amplitude of gravity wave power spectrum

Can compensate by increasing tilt (n_S) of density perturbation power spectrum

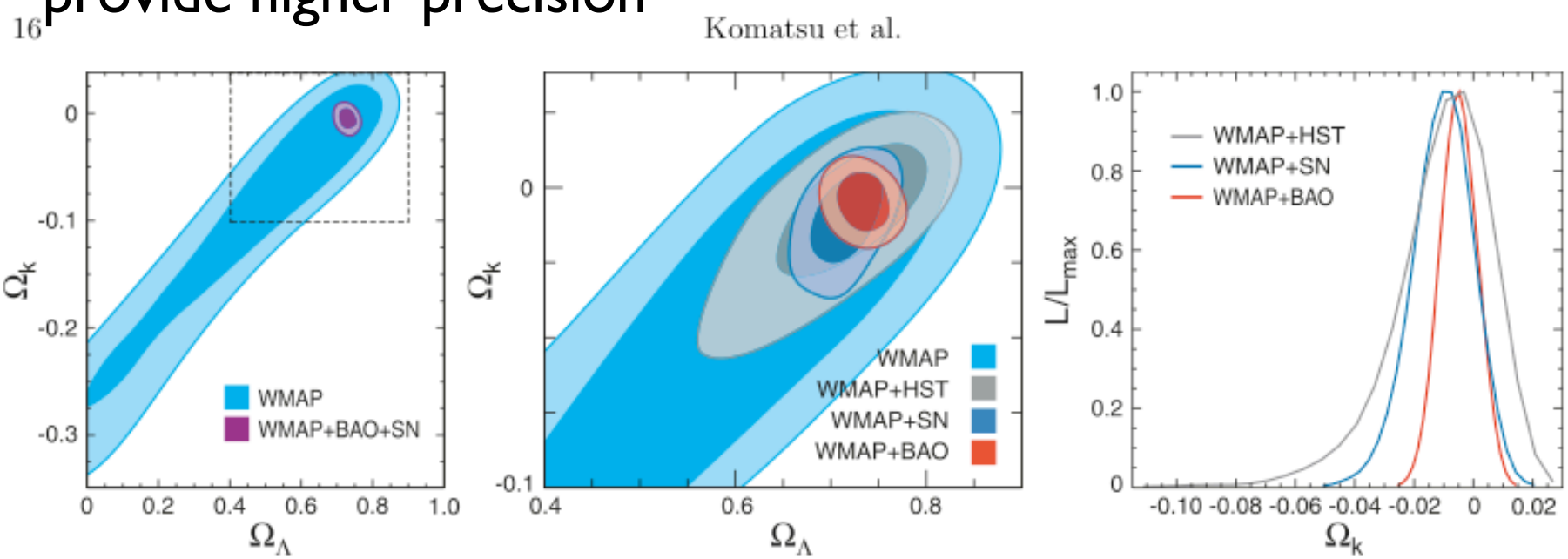
The $V(\phi) = \lambda\phi^4$ model is ruled out.

Mean Curvature

Expectation from inflation is that mean curvature (parameterized by Ω_K) is near 10^{-5} (or maybe 10^{-3} see Frievogel et al. 2006)

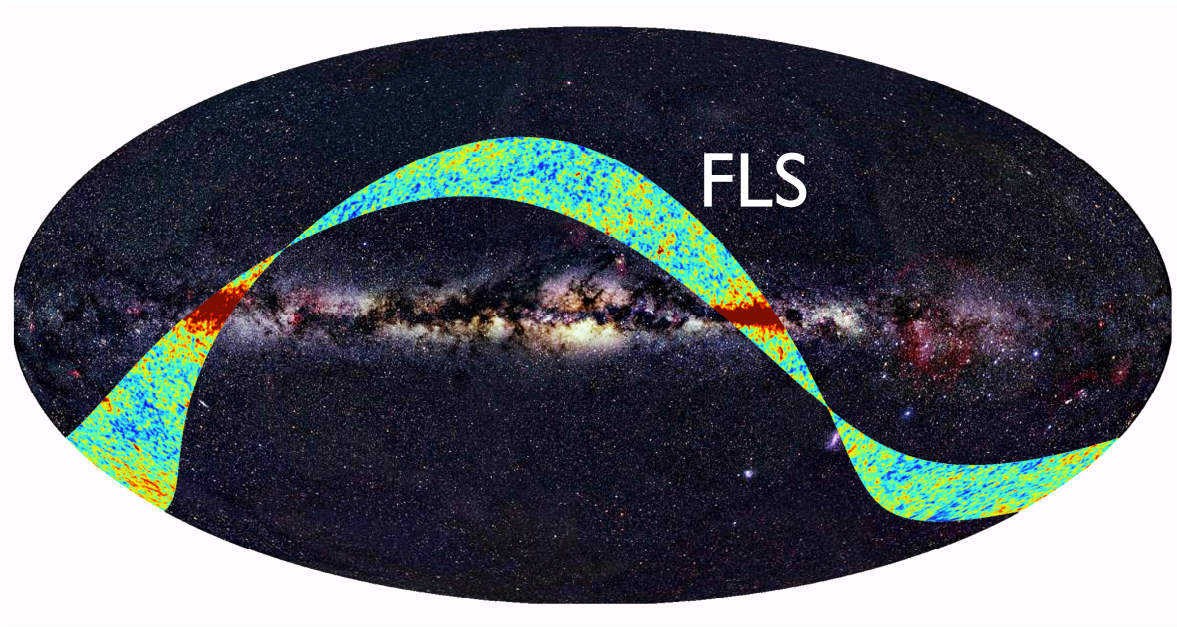
Would be very interesting to see non-zero Ω_K.

Combination of Planck and Dark Energy Experiments will provide higher precision



Planck

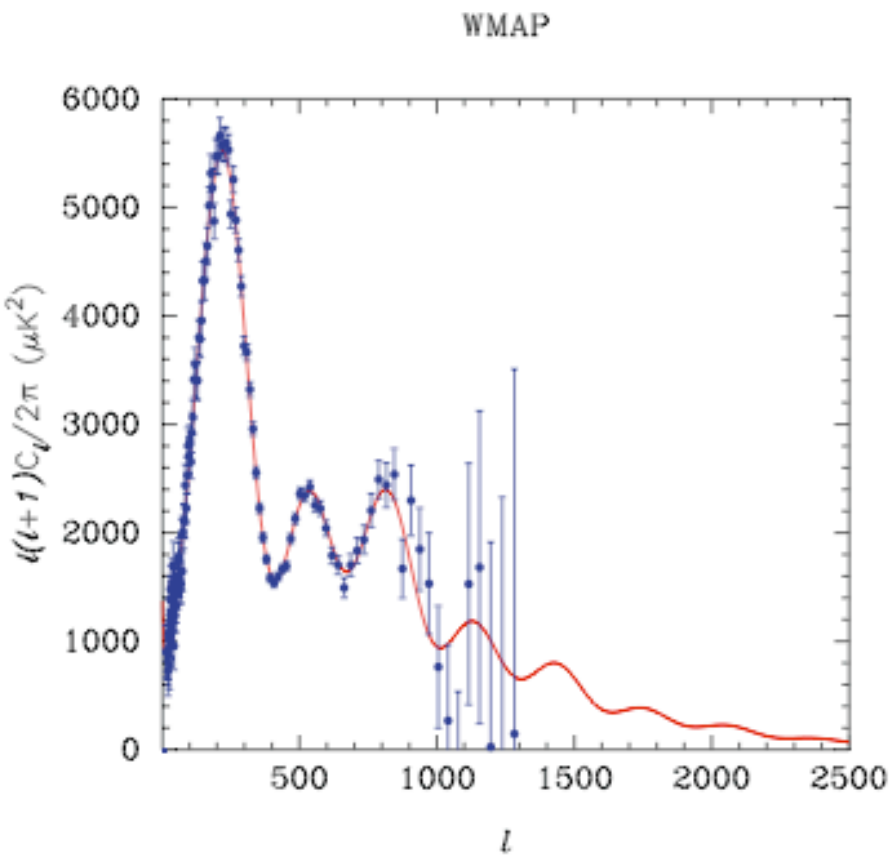
- An ESA mission with substantial contributions from NASA
- More frequency channels, higher-resolution and lower noise than WMAP
- Launched in May, 2009
- Maps from 'First Light Survey' released in September



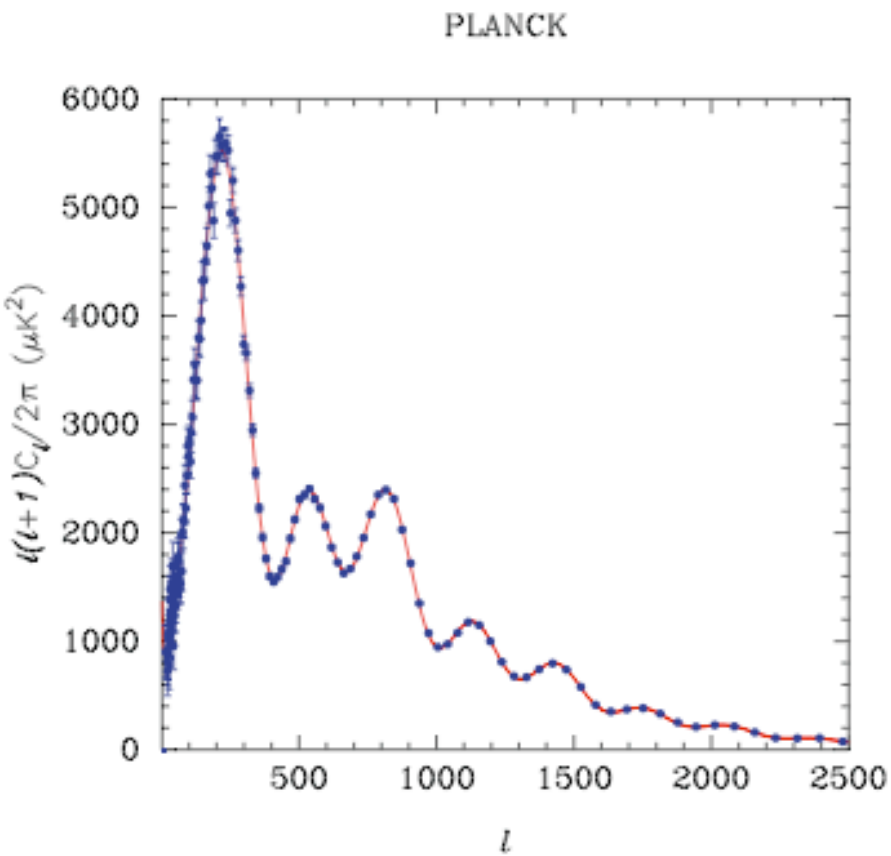
Over 80% of the sky has now been surveyed.

Next data release late 2012

(From simulations -- not real data)



WMAP 4 years

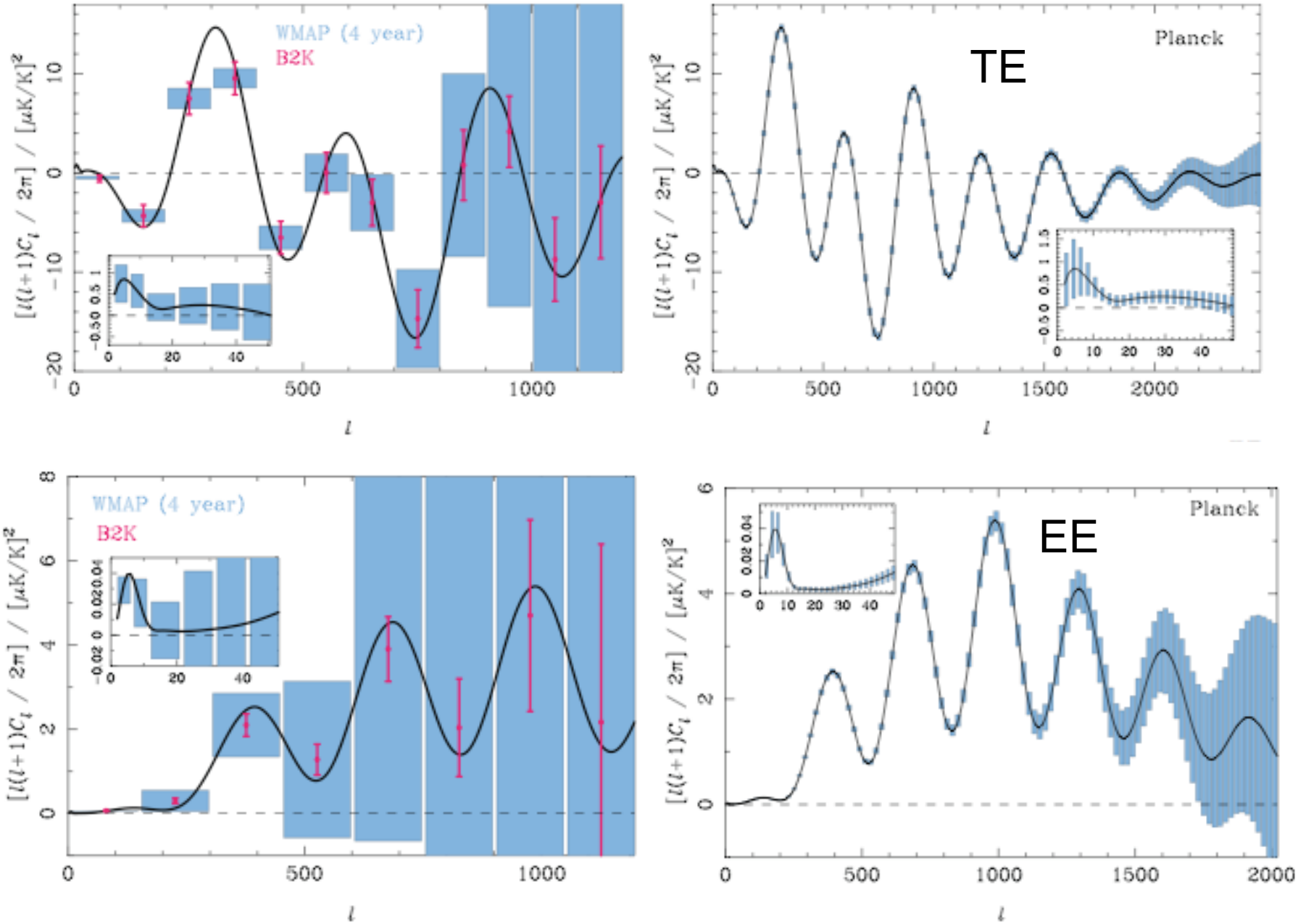


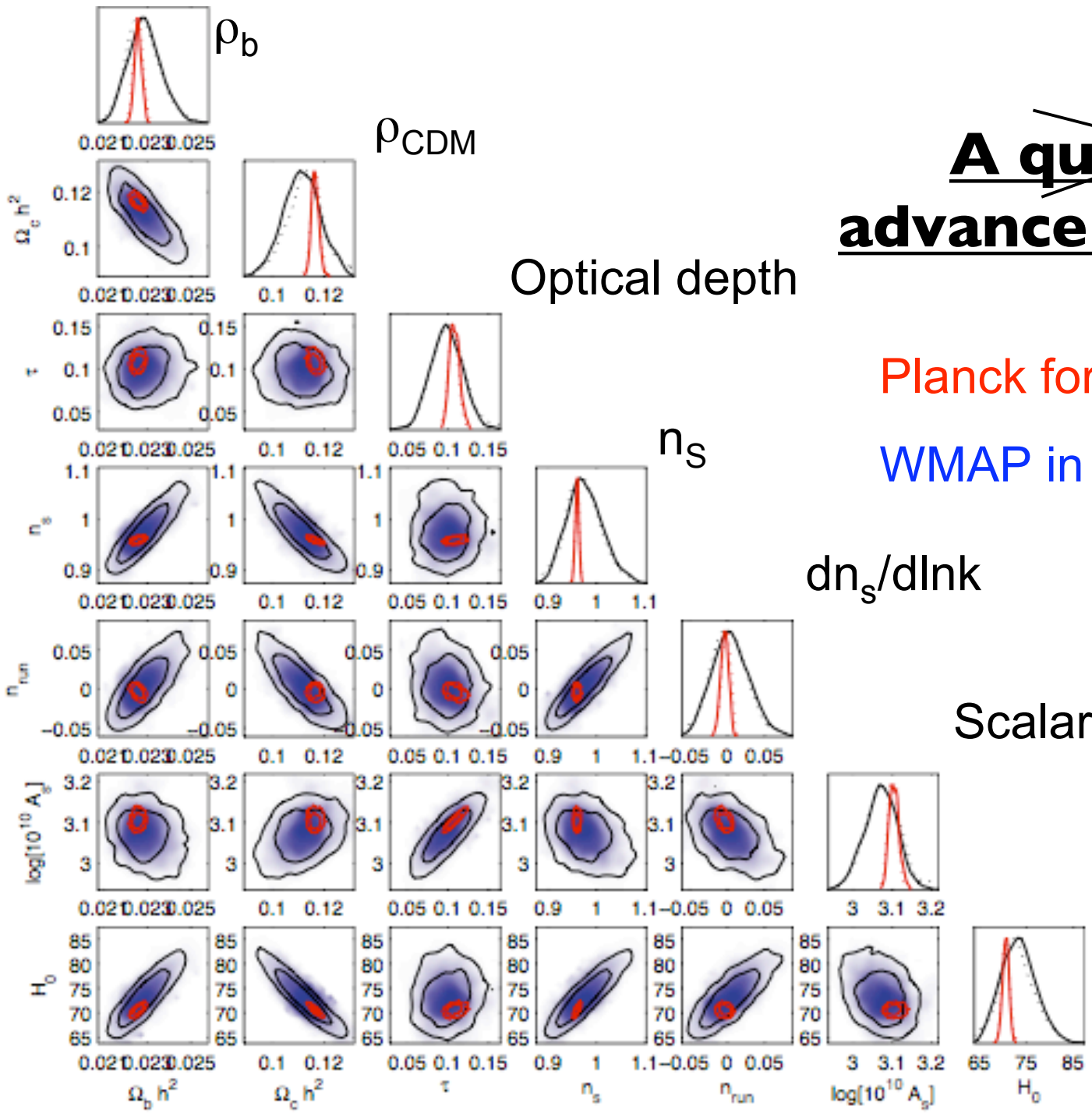
Planck 1 year

WMAP 4 years

Planck 1 year

Planck Bluebook





Revolutionary!

~~A qualitative~~

advance in precision

Planck forecast in red

WMAP in blue

Planck Bluebook

Planck and Model Dependence

- All parameter inferences from the CMB are highly indirect and therefore model dependent.
- Planck will enable us to test the models much better than can do with current data, reducing the model dependence.
- For example, allowing for isocurvature modes increases the uncertainty in the matter density by a factor of 4, given WMAP data, but only a factor of 1.5 given Planck data.

WMAP and Planck (and SPT)

A 10m telescope at the south pole with 5 times better resolution and 17 times as many detectors as Planck

SPT Team February 2007

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McGill

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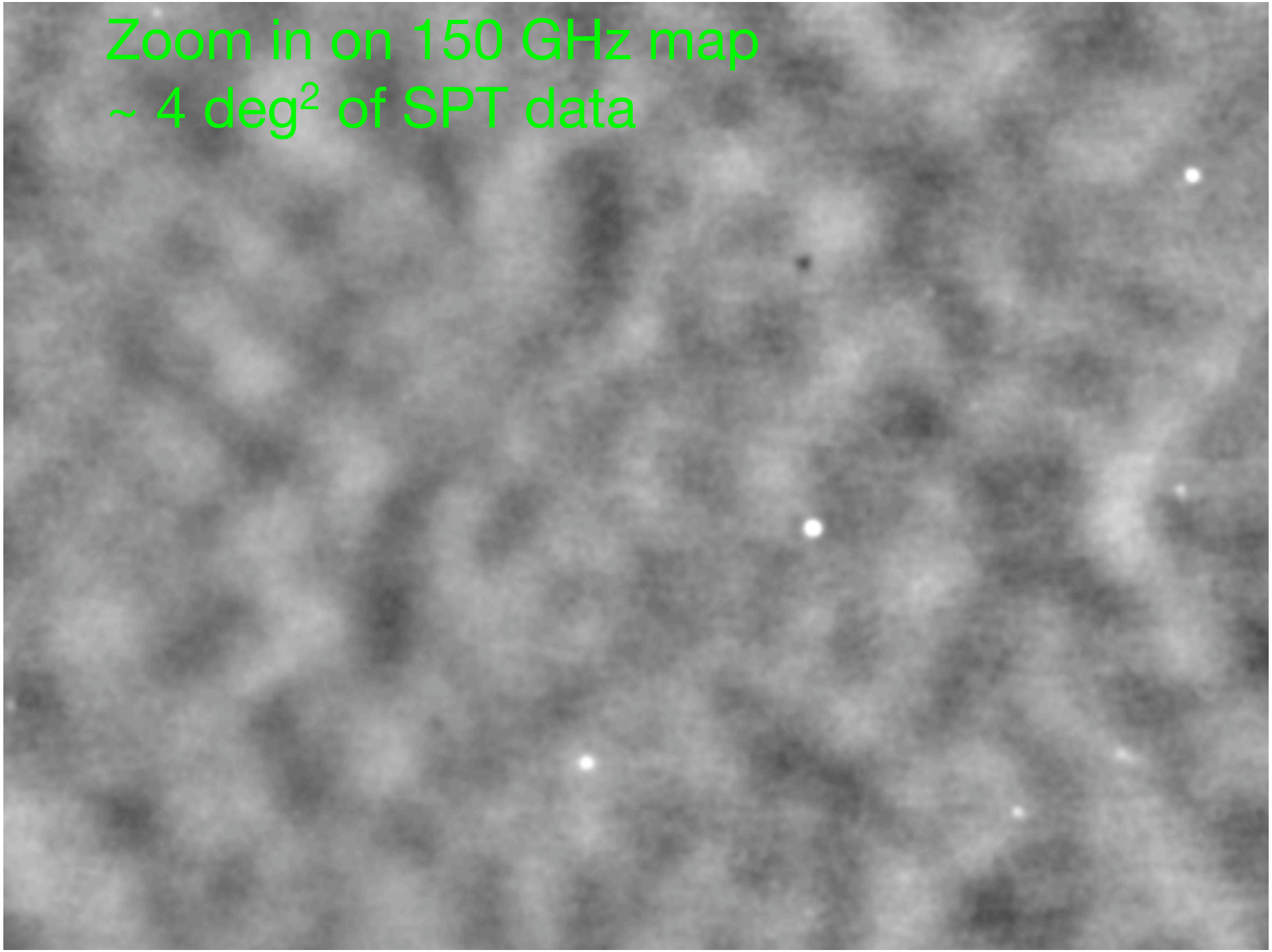
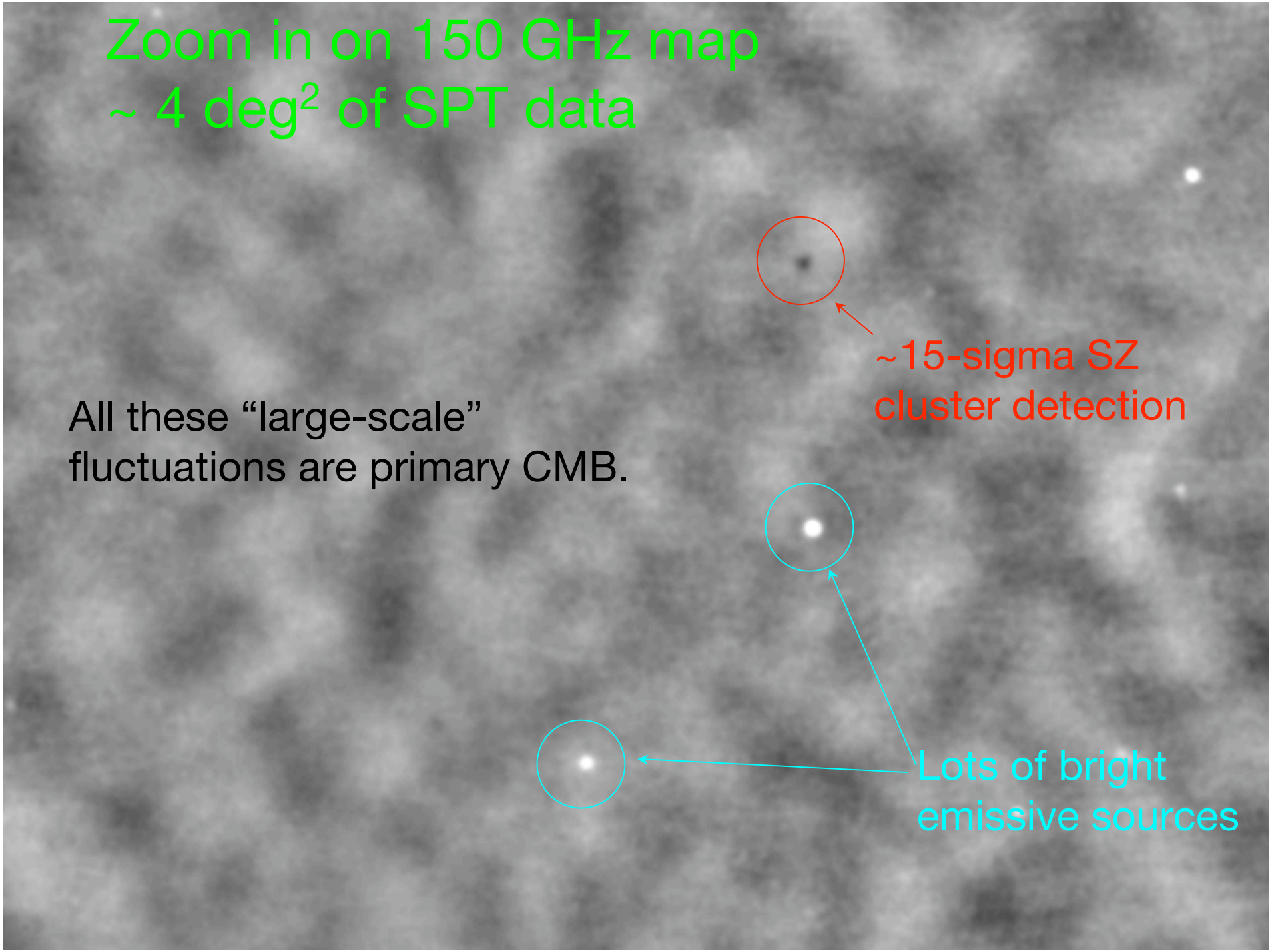
UC DAVIS UNIVERSITY OF CALIFORNIA

Case CASE WESTERN RESERVE UNIVERSITY

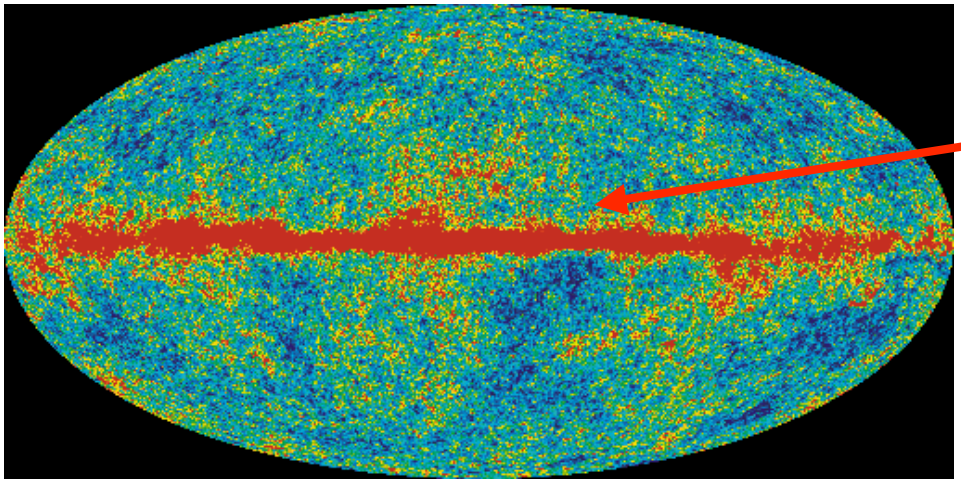
Colorado University of Colorado at Boulder

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD


Zoom in on 150 GHz map
~ 4 deg^2 of SPT data


Zoom in on 150 GHz map
~ 4 deg^2 of SPT data
~15-sigma SZ
cluster detection
All these “large-scale”
fluctuations are primary CMB.
Lots of bright
emissive sources

WMAP maps

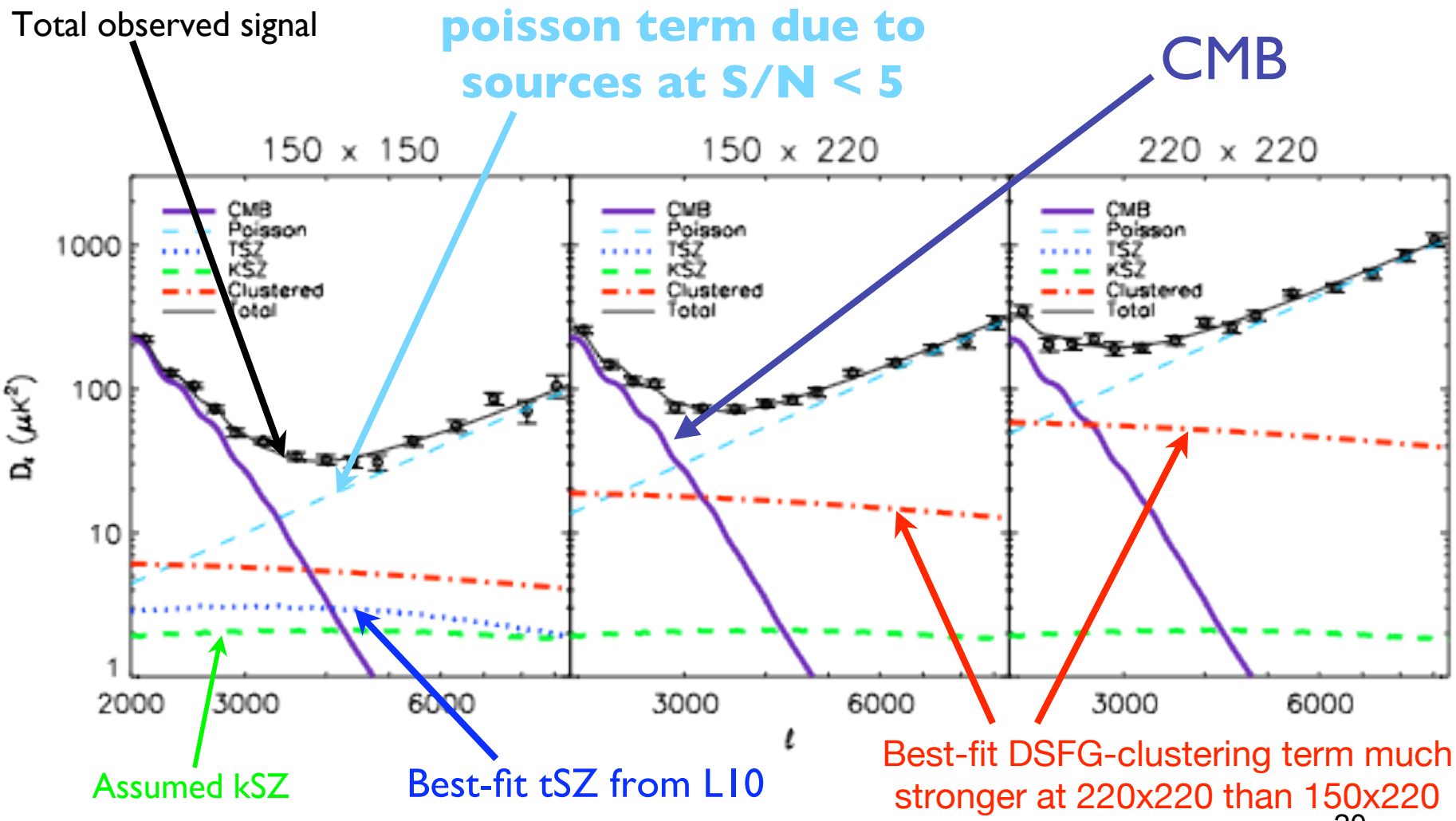


Full-sky 94 GHz intensity map

Galactic emission (synchrotron, free-free and thermal emission from interstellar dust)

All other galaxies are emitting like this as well

Auto and Cross-Frequency Power Spectra: Data and Model at l > 2000 (Hall et al. 2010)



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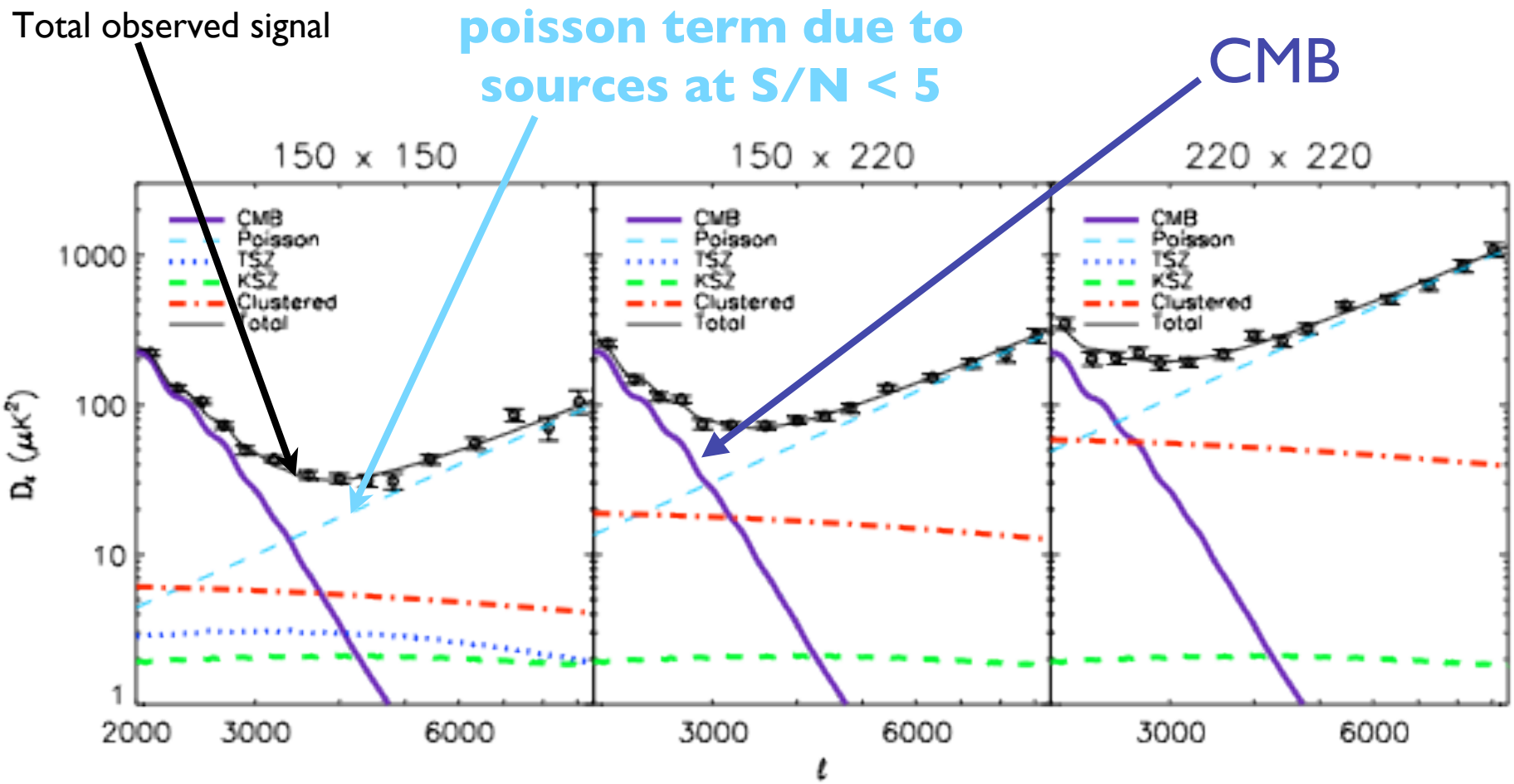


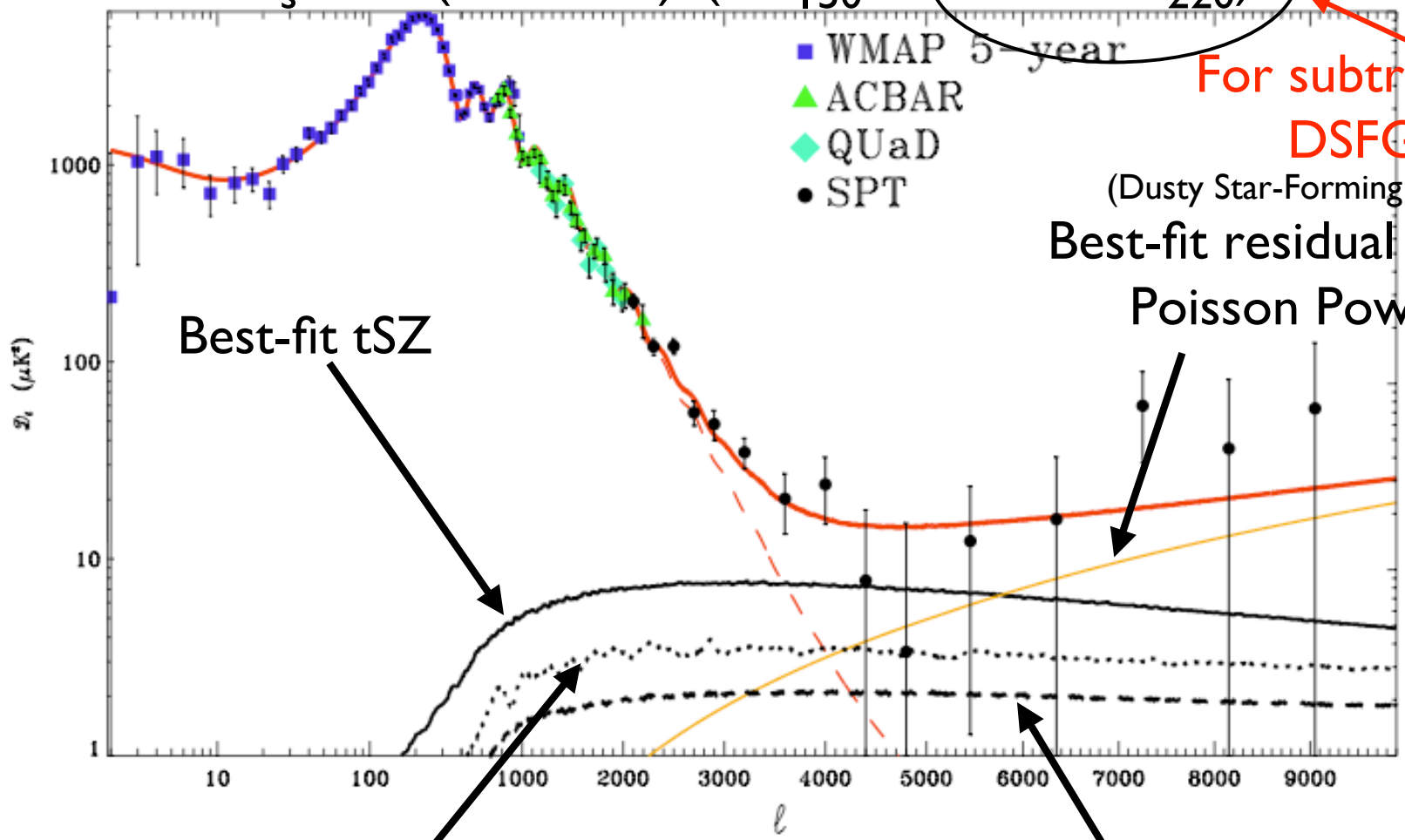
These signals are in the Planck data too -- SPT data are perfect for building a model to clean them out.

Lueker et al. 2010 (L10) bandpowers from subtraction

$$\delta T_s = 1/(1-0.325)\,(\delta T_{150} - 0.325\,\delta T_{220})$$

For subtracting DSFGs

(Dusty Star-Forming Galaxies)



Best-fit residual DSFG Poisson Power

Best-fit tSZ

Possible Patchy reionization signal (not included in modeling)

Assumed kSZ

Summary

- A time of rapid and significant progress with CMB observations due to Planck, SPT and others.
- Further observations will increase precision dramatically, increase ‘discovery space’, and decrease model dependence of current parameter constraints.
- CMB is perhaps most interesting as a probe of inflation and the initial conditions for structure formation. It’s important for ‘calibration’ of dark energy experiments.