Planck polarisation status and small scales

Planck Collaboration
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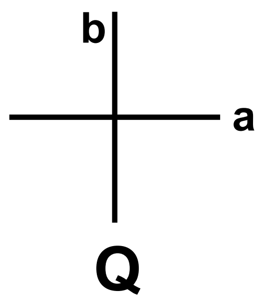
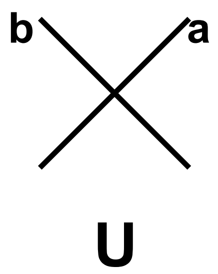
Planck polarisation measurements

- **Planck polarimetry**
  - Planck detectors are sensitive to linear polarisation

$$s = \frac{1}{2}\left[(1+\epsilon)\,\mathcal{I} + (1-\epsilon)\Big(\mathcal{Q}\ cos(2\psi) + \mathcal{U}\ sin(2\psi)\Big)\right]$$

  - Planck uses combination of orthogonal detectors to get Q and U :

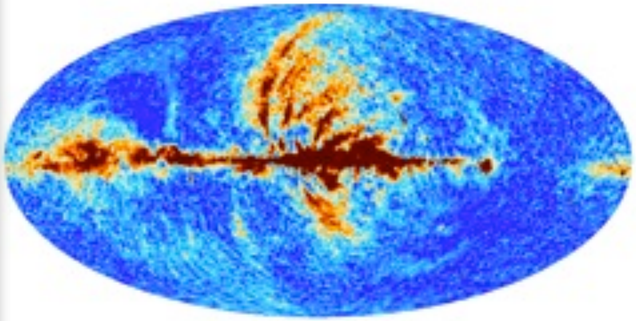




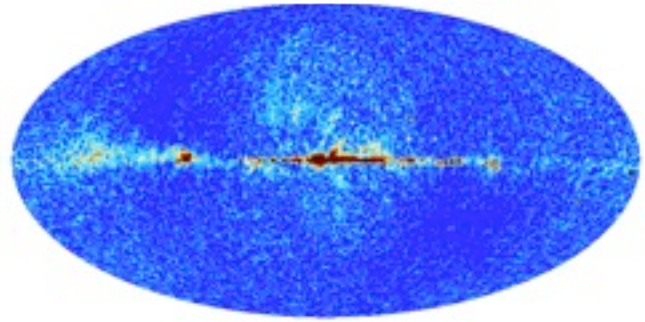
- **polarisation is challenging**
  - any **differential calibration error** between pairs of detectors causes **leakage** of total intensity into the polarization maps (such as gain calibration error or different spectral transmissions),
  - the response of each detector to polarization is difficult to **calibrate** (due to the lack of celestial standard sources),
  - the amplitude of the **polarized CMB signal is low**

polarised intensity maps

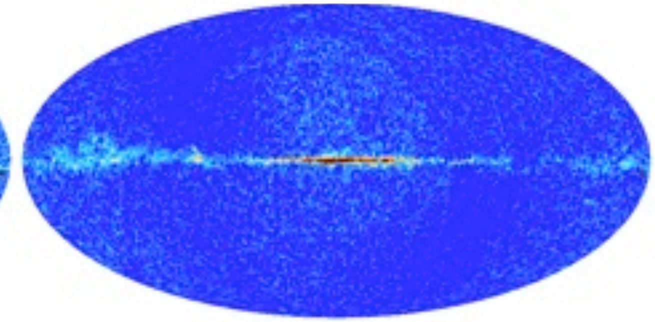
30 GHz



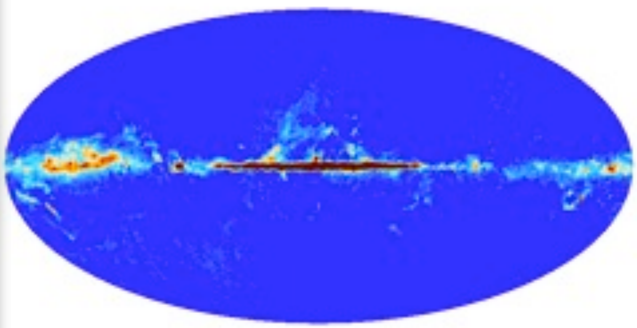
44 GHz



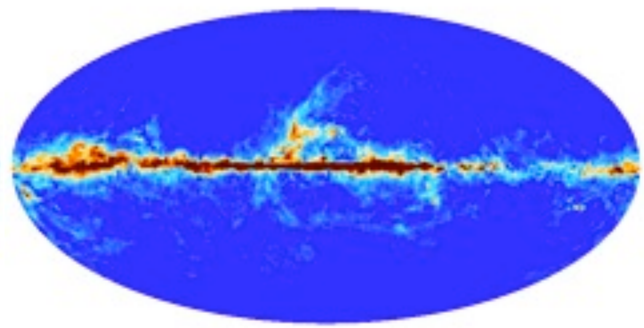
70 GHz



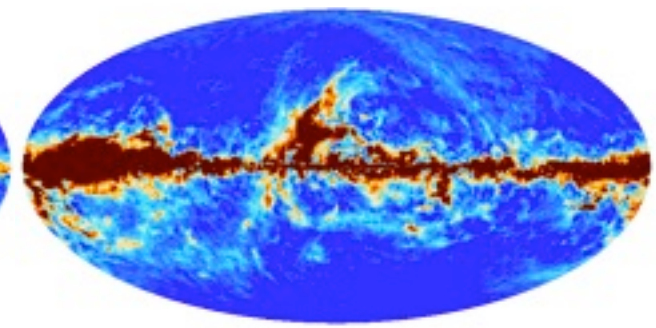
100 GHz



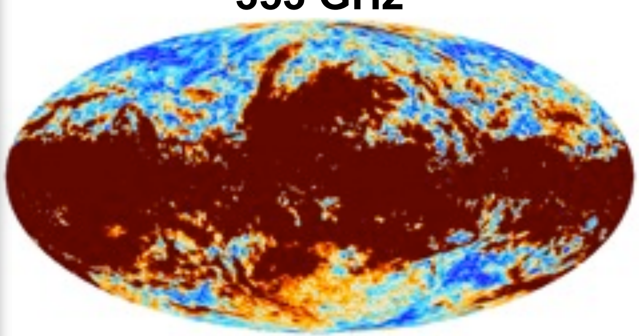
143 GHz



217 GHz



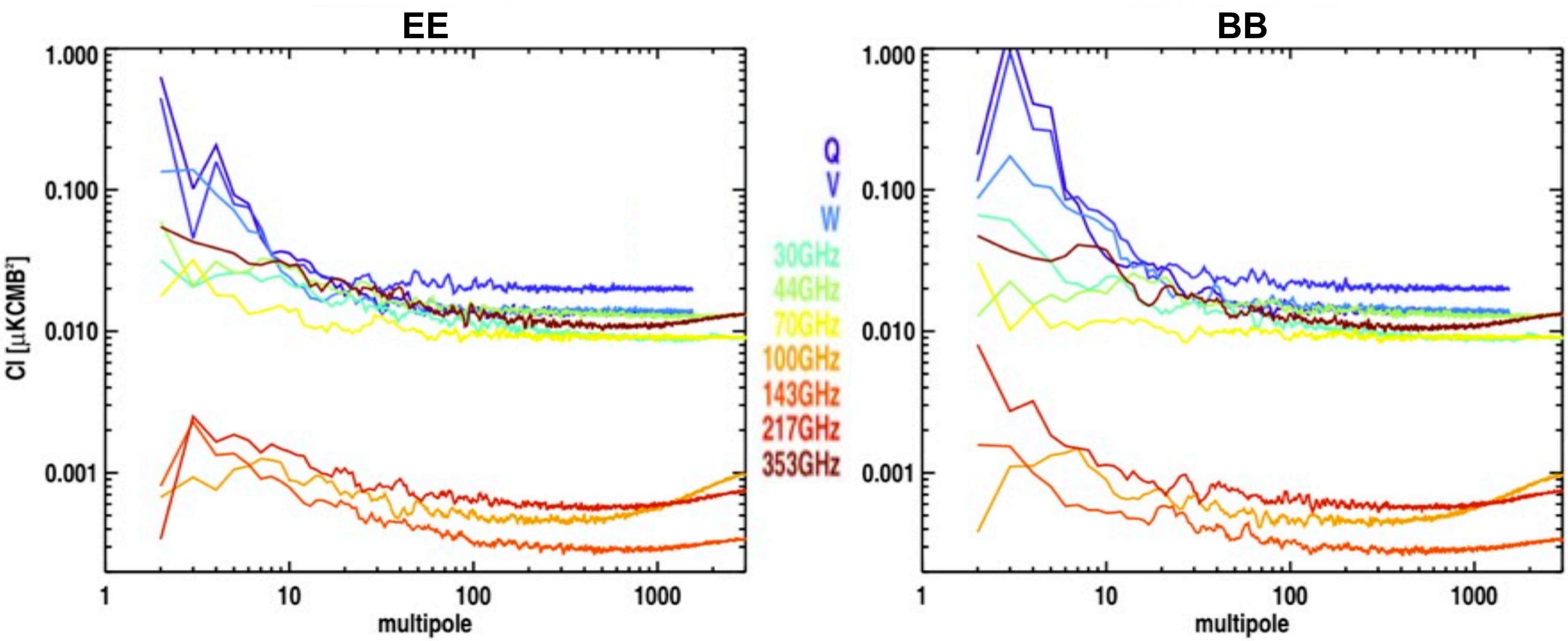
353 GHz



PLANCK polarised maps are dominated by foreground emissions from 30 to 353 GHz

noise level in polarisation

preliminary



LFI and HFI noise (half-ring half difference)
WMAP noise (DA half-difference)

Planck systematics for polarisation

• Leakage from intensity to polarisation

due to Planck scanning strategy, we need to combine detector measurements to reconstruct (I,Q,U) maps. Any differential calibration between pairs of detectors induces leakage from total intensity into the polarization maps :

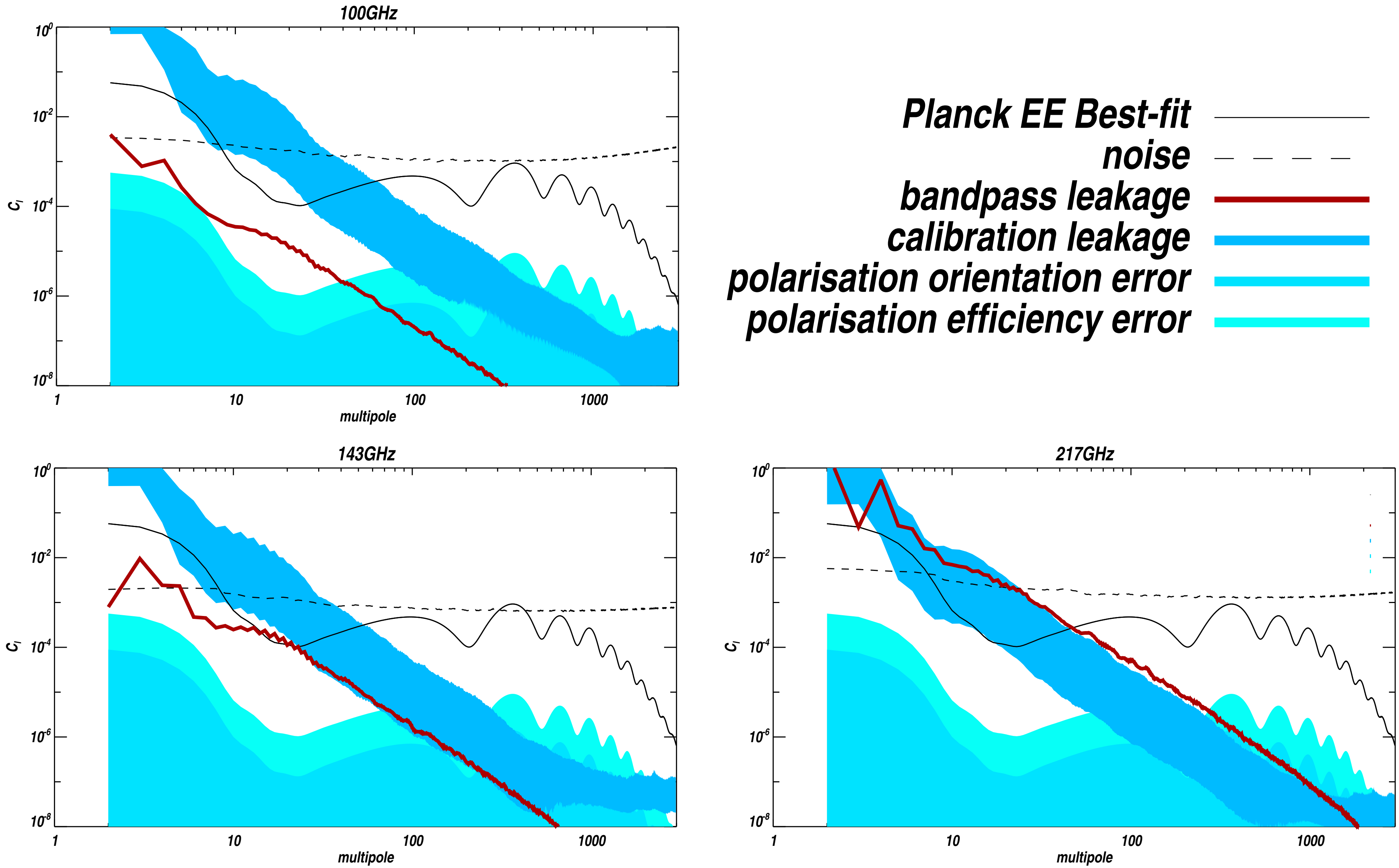
- gain variation	**large scales**
- bandpass mismatch	**large scales**
- calibration mismatch	**large scales**

• Other systematics

other systematics for polarisation are already sub-dominant

- Far Side Lobes	**large scales**
- noise correlation	**small/large scales**
- polarisation angle and polarisation efficiency	**small scales**
- beam mismatch	**small scales**

Planck systematics for polarisation

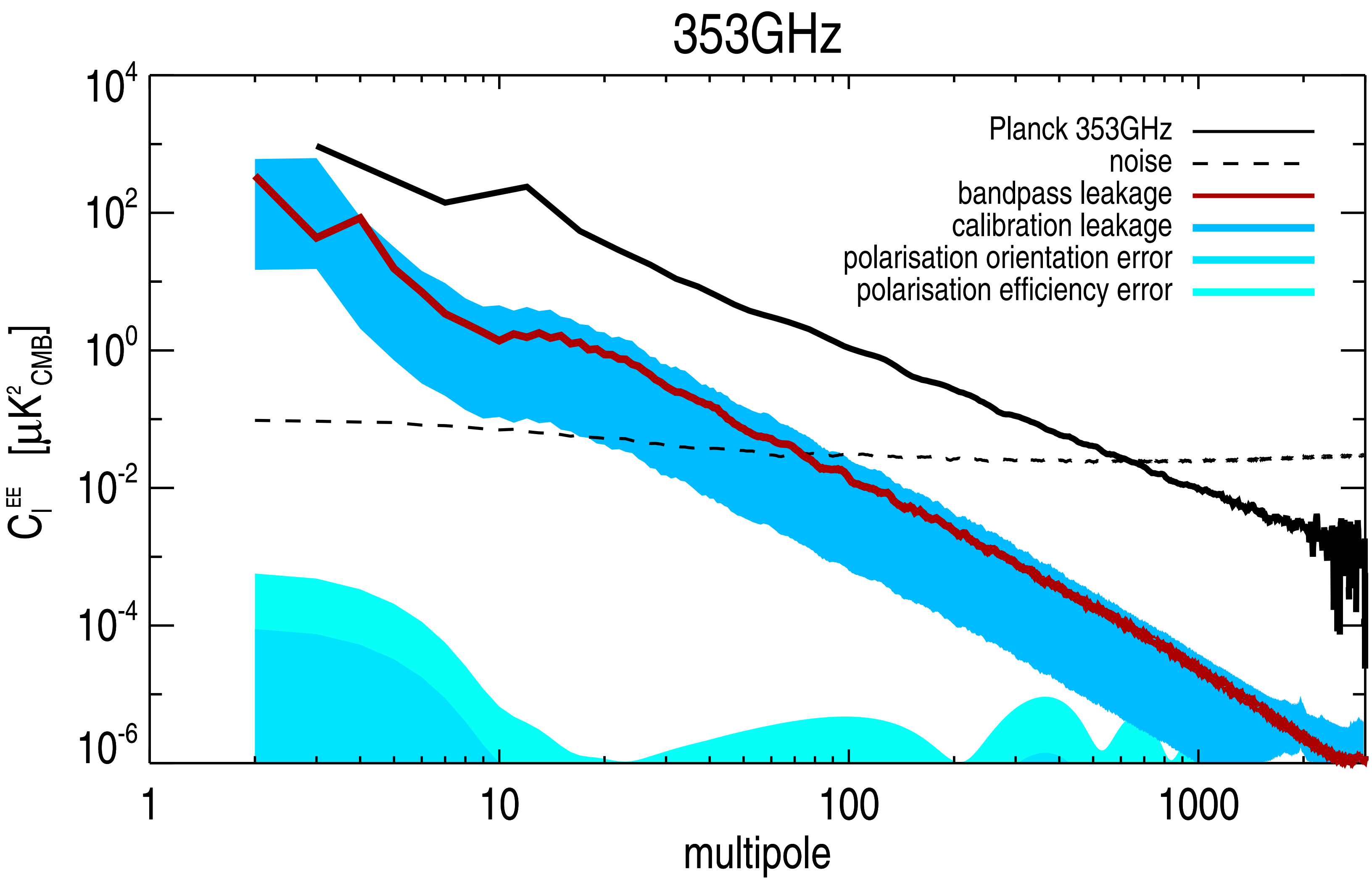


systematics are dominant over CMB signal at large scales

[Planck 2013 results. VI. High Frequency Instrument data processing]

Interstellar Dust polarisation emissions

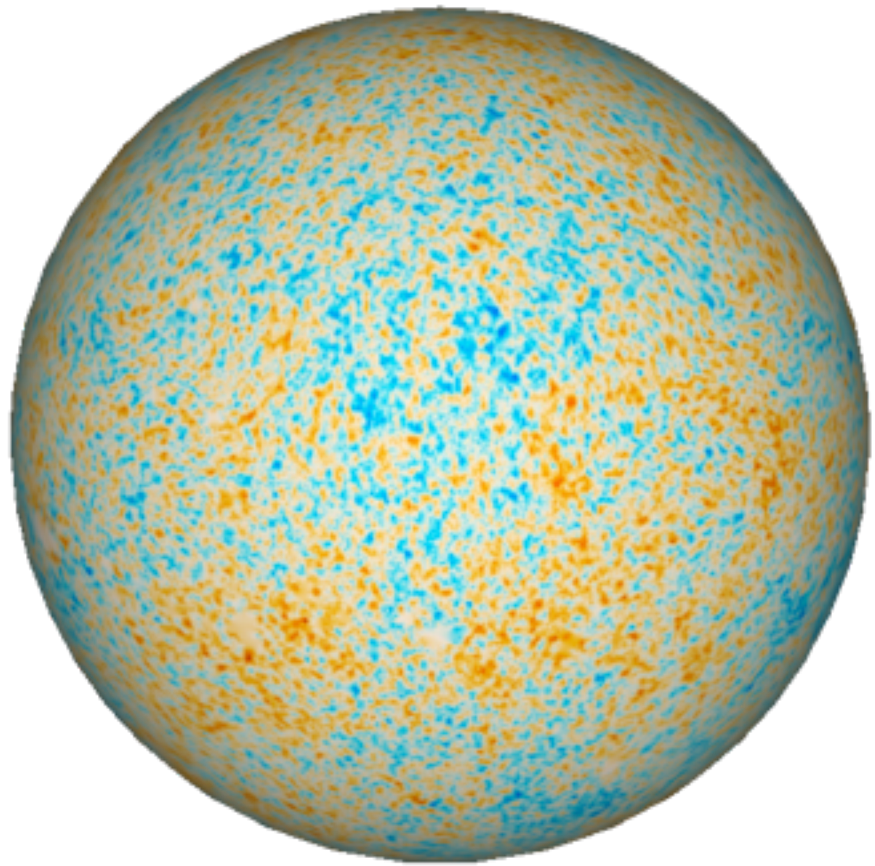
for Galactic studies at high frequency (353GHz), signal-to-noise ratio is much higher and thus Planck is less sensitive to systematics



spectra on 90% of the sky

[cf. Planck Collaboration talks (by F. Boulanger & J. Aumont)]

Planck polarised CMB results
(Small Scales Teaser)



peak-polarisation correlation

• Principle

- **adiabatic scalar fluctuations** predict a specific polarization pattern around CMB temperature extrema (so called cold and hot spots)
- **profile of spots** in the temperature extrema radial frame $Q_r(\theta)$ and $U_r(\theta)$ is derived from the statistics of peaks of Gaussian random fields with spectra $\mathbf{C_\ell^{TE}}$ and $\mathbf{C_\ell^{TB}}$

• Method

- we detect minima and maxima in the Planck CMB temperature map for different resolutions : 2, 1 and 0.5 degree
  for 0.5°, on 71% of the sky : 11396 cold spots and 10468 hot spots consistent with the ΛCDM Planck model prediction (11073 spots)
- we produce a polarized ILC map, using channels between 70 and 353 GHz
- we stack 4°×4° square maps for I, Q and U around each spot
- Q and U stacked maps are then rotated in the temperature extrema radial frame $Q_r(\theta)$ and $U_r(\theta)$ [Kamionkowski et al. 1997]

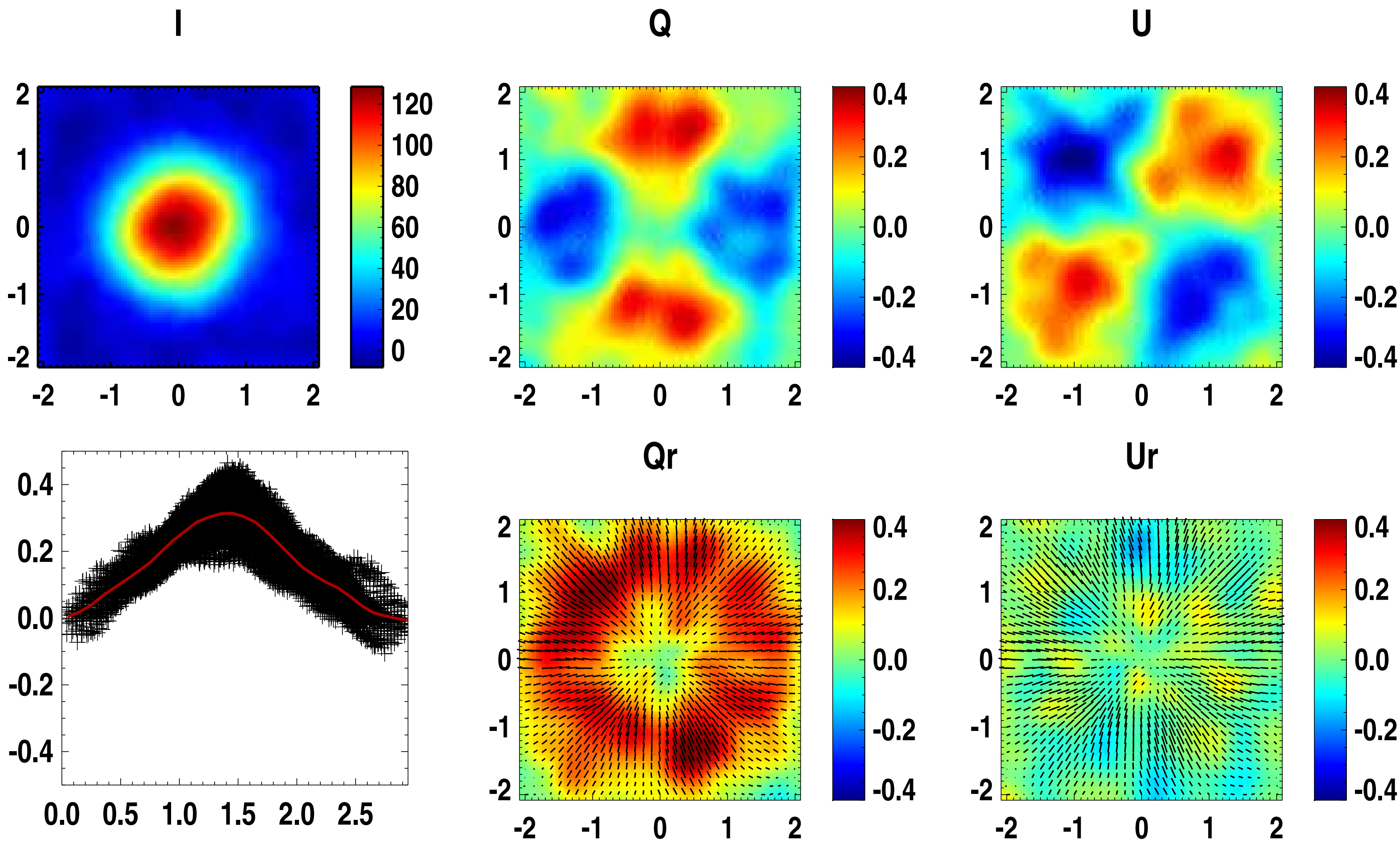
• Standard Model

temperature hot spots correspond to potential wells (i.e., over-dense regions) at the surface of last scattering; therefore, matter flows towards these hot spots:

- at the acoustic scale ($\theta_A \equiv r_s/d_A \approx 0.6°$), the flow is decelerating due to the central photon pressure, which creates a **tangential pattern**
- at twice the acoustic scale (~1.2°), the flow of matter is accelerating due to gravity, which creates a **radial polarization pattern**

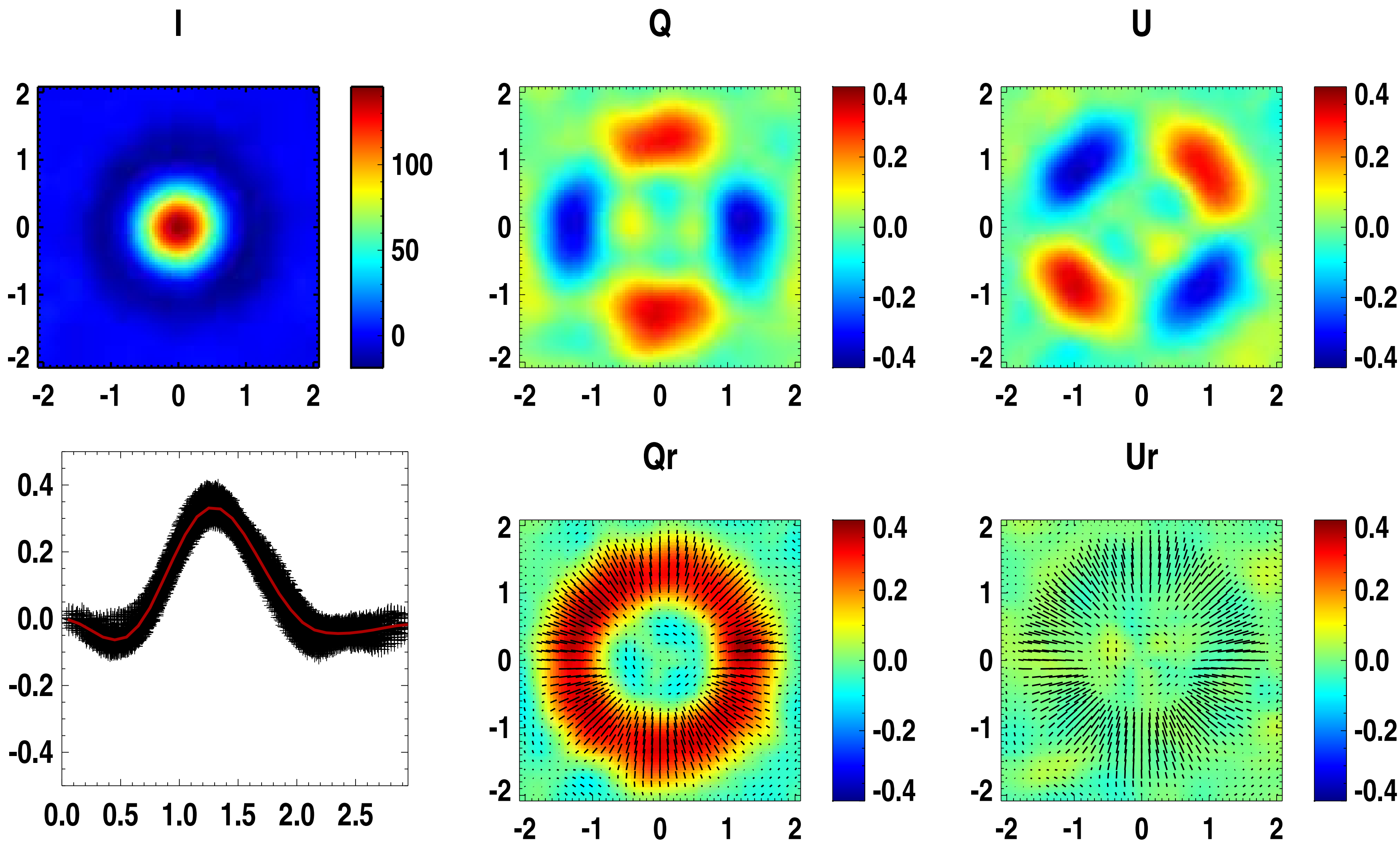
peak-polarisation correlation

resolution 2 deg



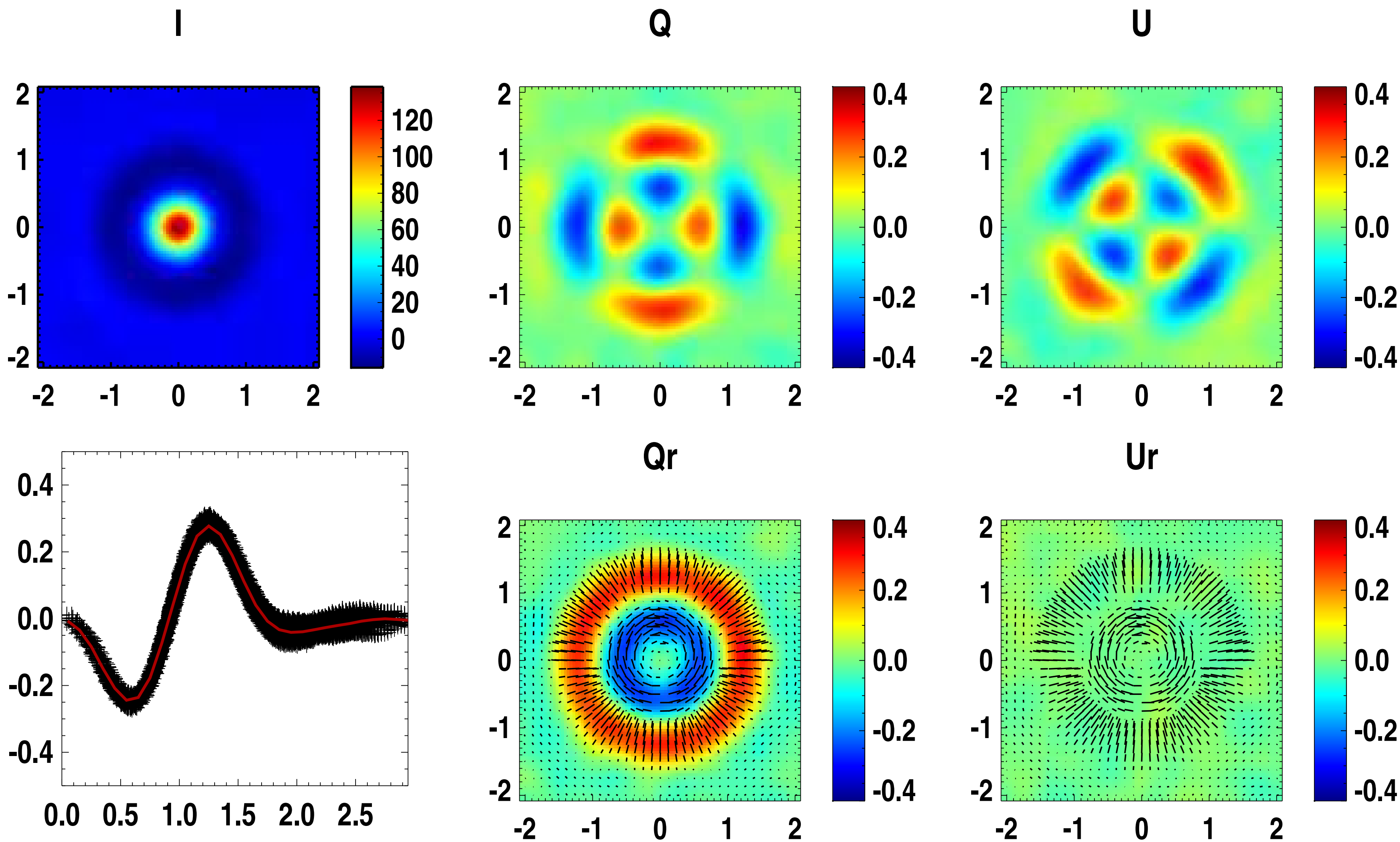
peak-polarisation correlation

resolution 1 deg



peak-polarisation correlation

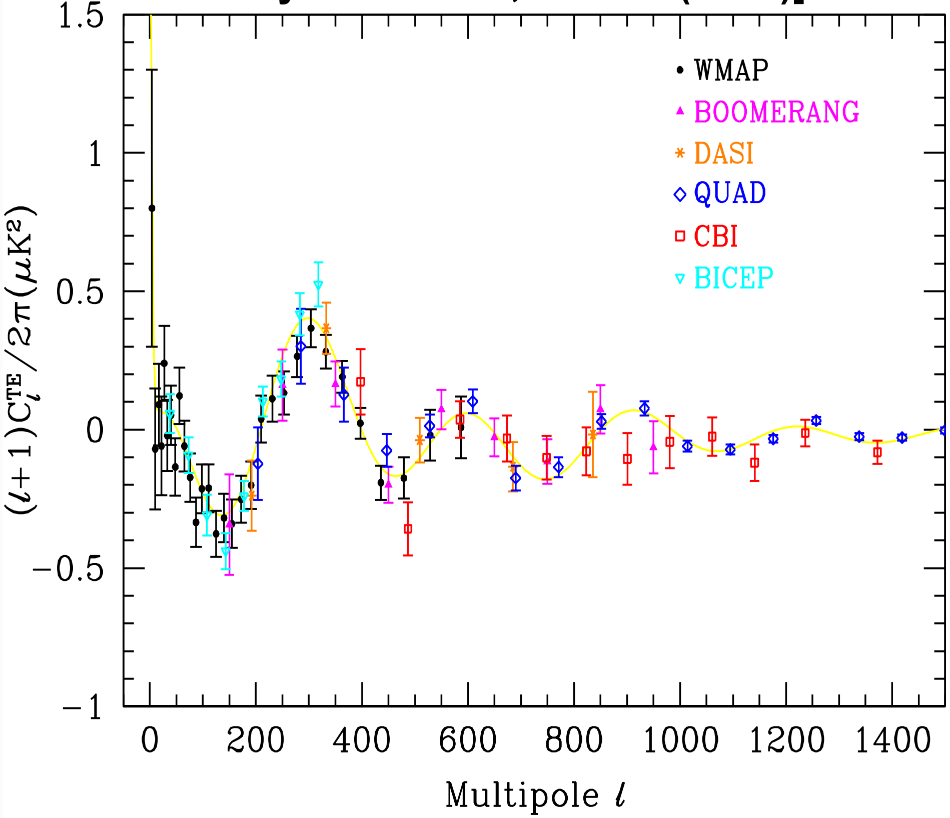
resolution 0.5 deg



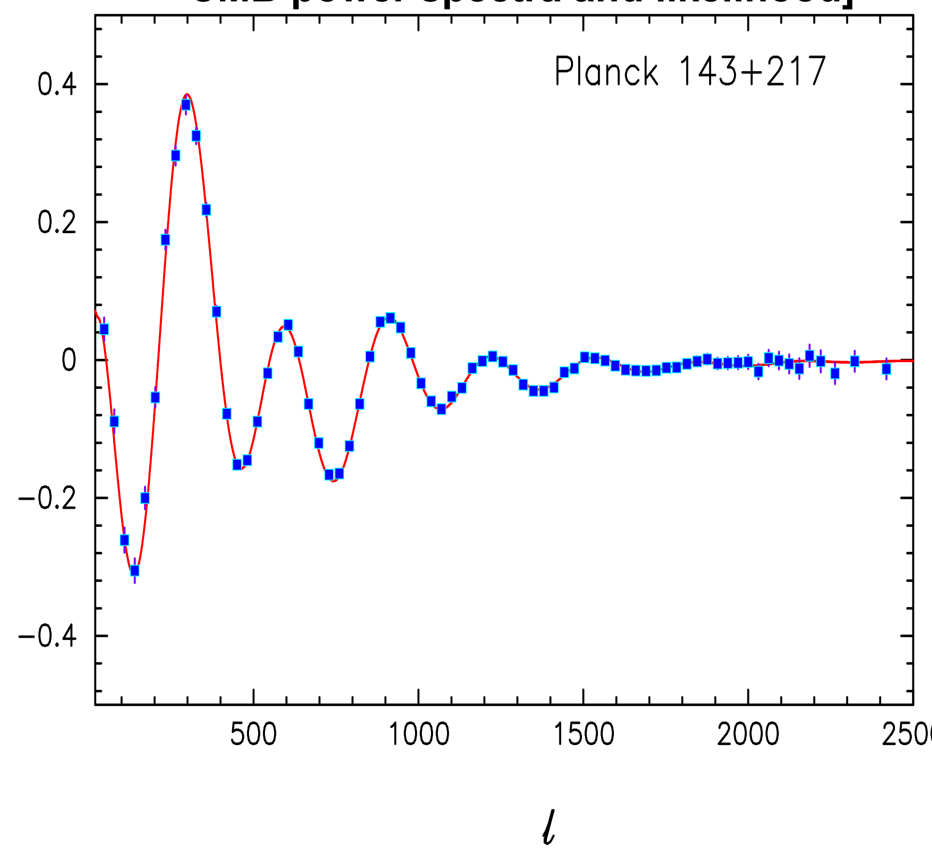
97σ detection (10σ for WMAP)

TE CMB power spectra

[J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012)]



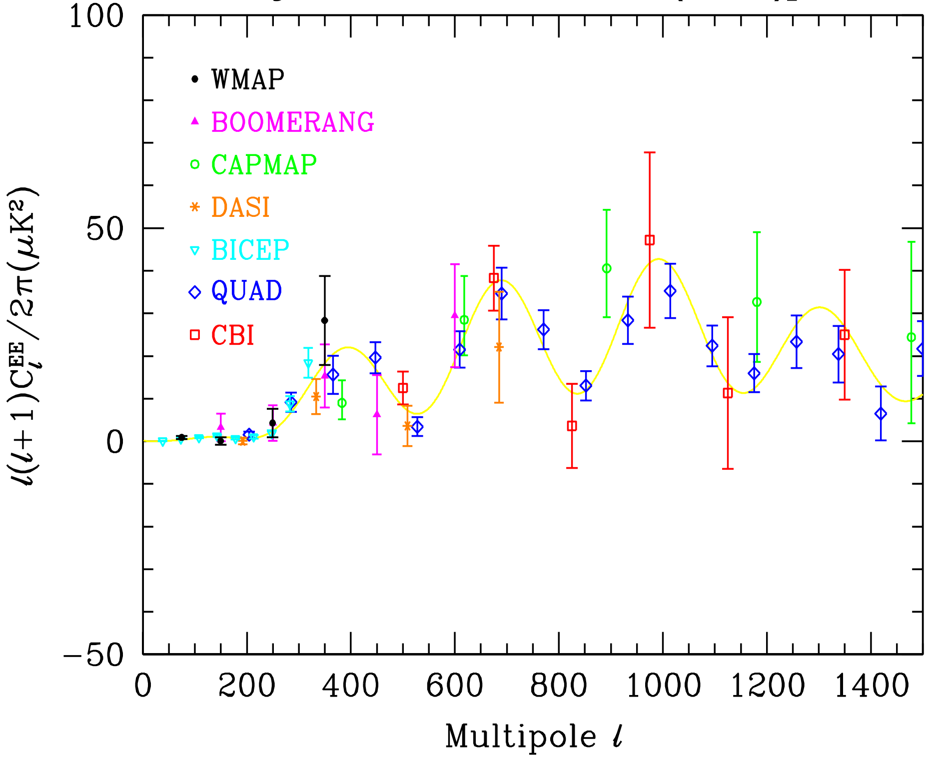
[Planck 2013 results. XV CMB power spectra and likelihood]



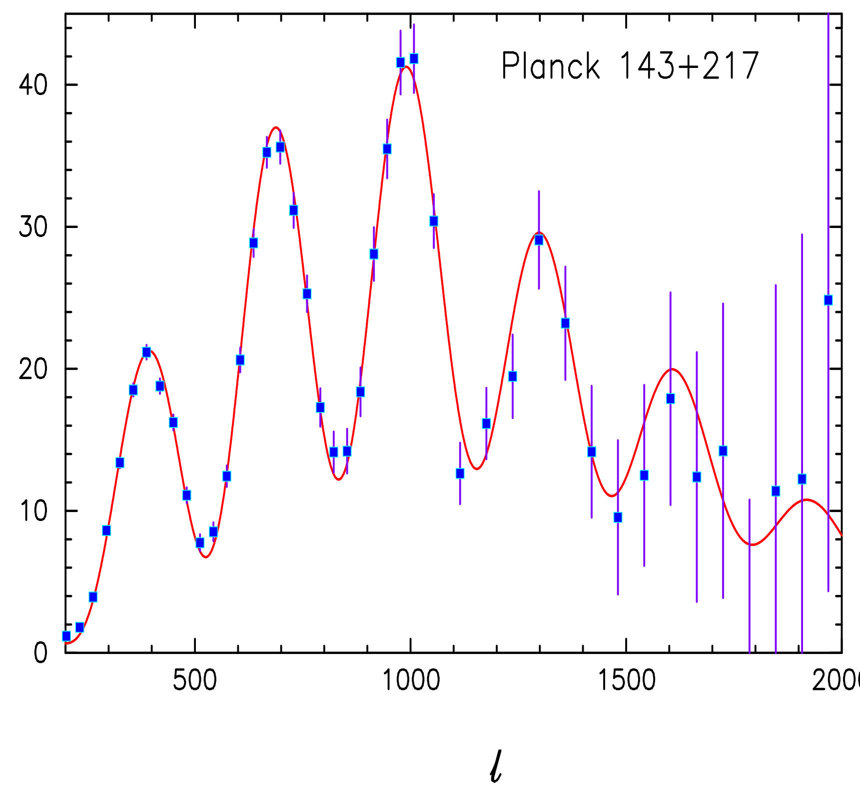
impressive consistency with the Planck best-fit model based only on temperature (Planck+WP+HighL)

EE CMB power spectra

[J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012)]



[Planck 2013 results. XVI. Cosmological parameters]



impressive consistency with the Planck best-fit model based only on temperature (Planck+WP+HighL)

Planck polarisation in 2013 release

- the **sensitivity** and **accuracy** of Planck's polarized maps is already well beyond that of any previous survey in this frequency range
- some **systematic** effects are not yet resolved at a level satisfactory for cosmological analysis at large angular scales (l <100)

polarization is not delivered in the 2013 release

BUT

- at small angular scales systematic effects are sub-dominant and uncertainties are dominated by residual detector noise.
  CMB polarization is being measured by Planck with unprecedented sensitivity at angular scales smaller than a few degrees.
- thanks to higher signal-to-noise ratio, Planck data allow new scientific investigations of **diffuse Galactic polarized emissions** and the **magnetic fields** that induce them

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada

Planck is a project of the European Space Agency, with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.