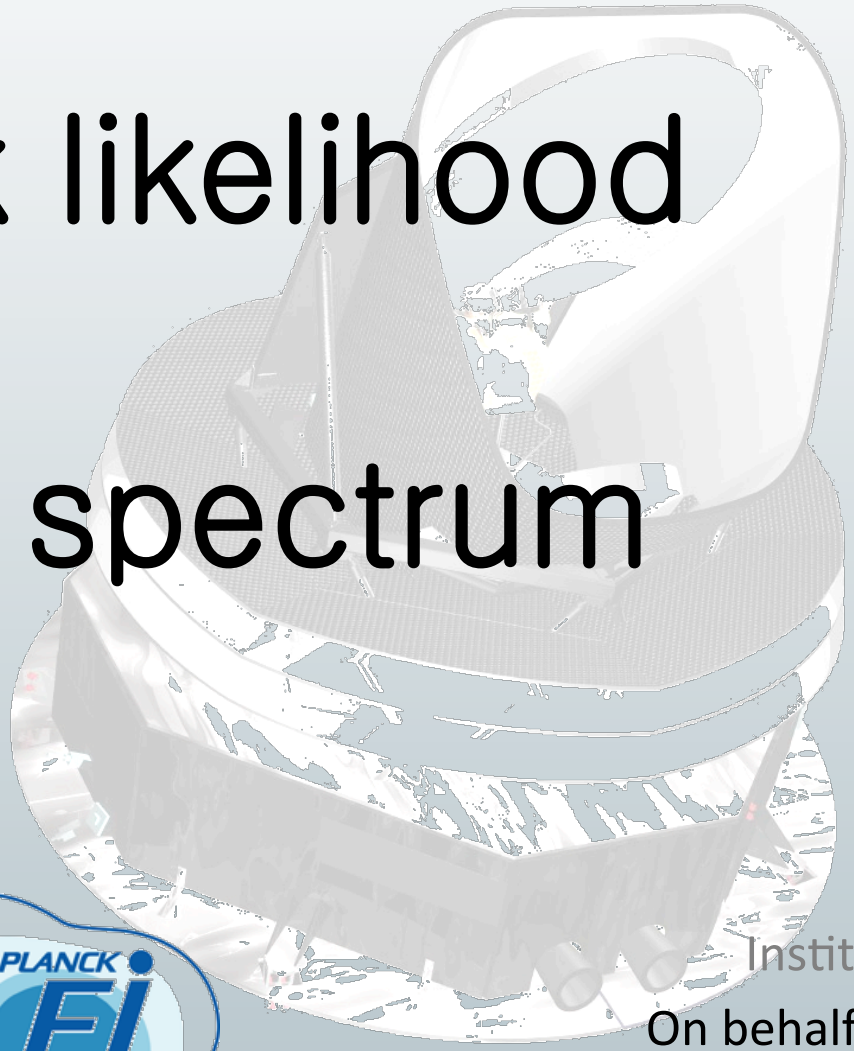
Planck likelihood and power spectrum



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On behalf of the Planck collaboration

ESLAB, April 2d, 2013

Methodology

- Hybrid multi-frequency likelihood approach
  - Large scales (LL): Gaussian likelihood on maps
  - Small scales (HL): Gaussian likelihood approx. on spectra
- Foregrounds:
  - LL: Parametrised at the map level, Gibbs marginalisation
  - HL: Parametrised at the spectral level
- Validation:
  - Data selection & technical choices
  - Null tests
  - Simulations
  - Foreground cleaned CMB maps, LFI 70 GHz (HL)

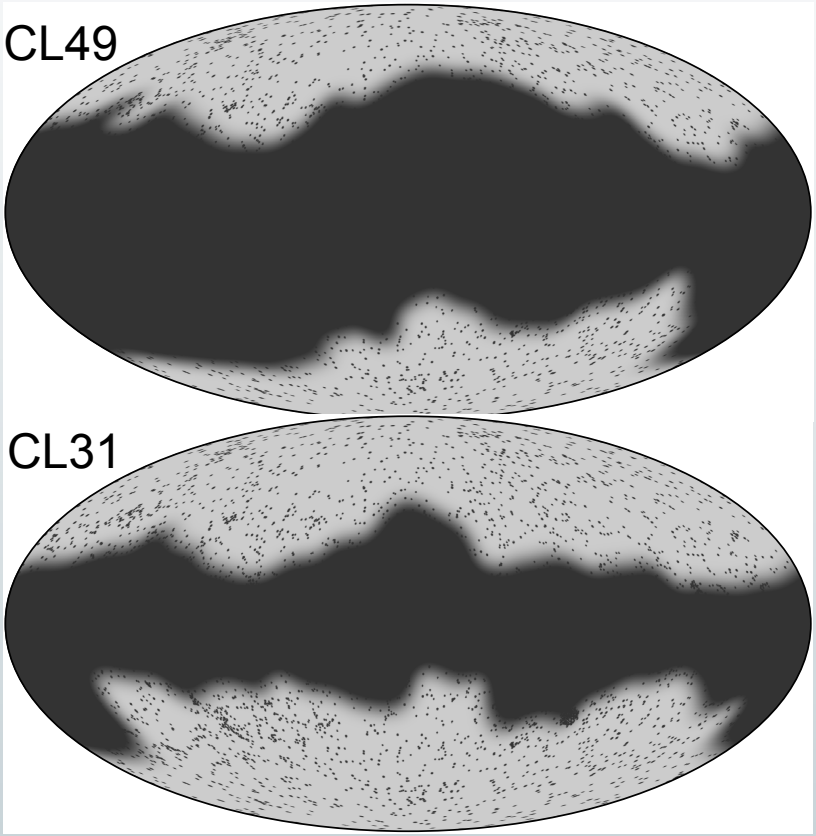
HL specific methodology

- Mask and beam deconvolved power spectra (Master/Spice) for 56 detector pairs in the 100-217 GHz range
- Data compression into 4 combined cross-spectra:
  - 100x100, 143x143, 143x217, 217x217 GHz
  - Re-calibrate cross-spectra within a given frequency pair
  - Optimally combine cross-spectra within a frequency pair
  - Produce inter-frequency calibration priors
  - Galactic dust residual correction
- Parametrised foreground power spectrum templates:
  - CIB clustered: 4 parameters (3 amplitudes, one spectral index)
  - Poisson from unresolved sources: 4 parameters (amplitudes)
  - tSZ, kSZ: 2 parameters (amplitudes)
  - tSZxCIB correlation: 1 parameter
- Fiducial gaussian approximation, covariance includes:
  - CMB + noise (correlated, anisotropic) + foregrounds
  - Beam errors marginalisation (using priors on error eigenmodes)

HL: conservative data selection

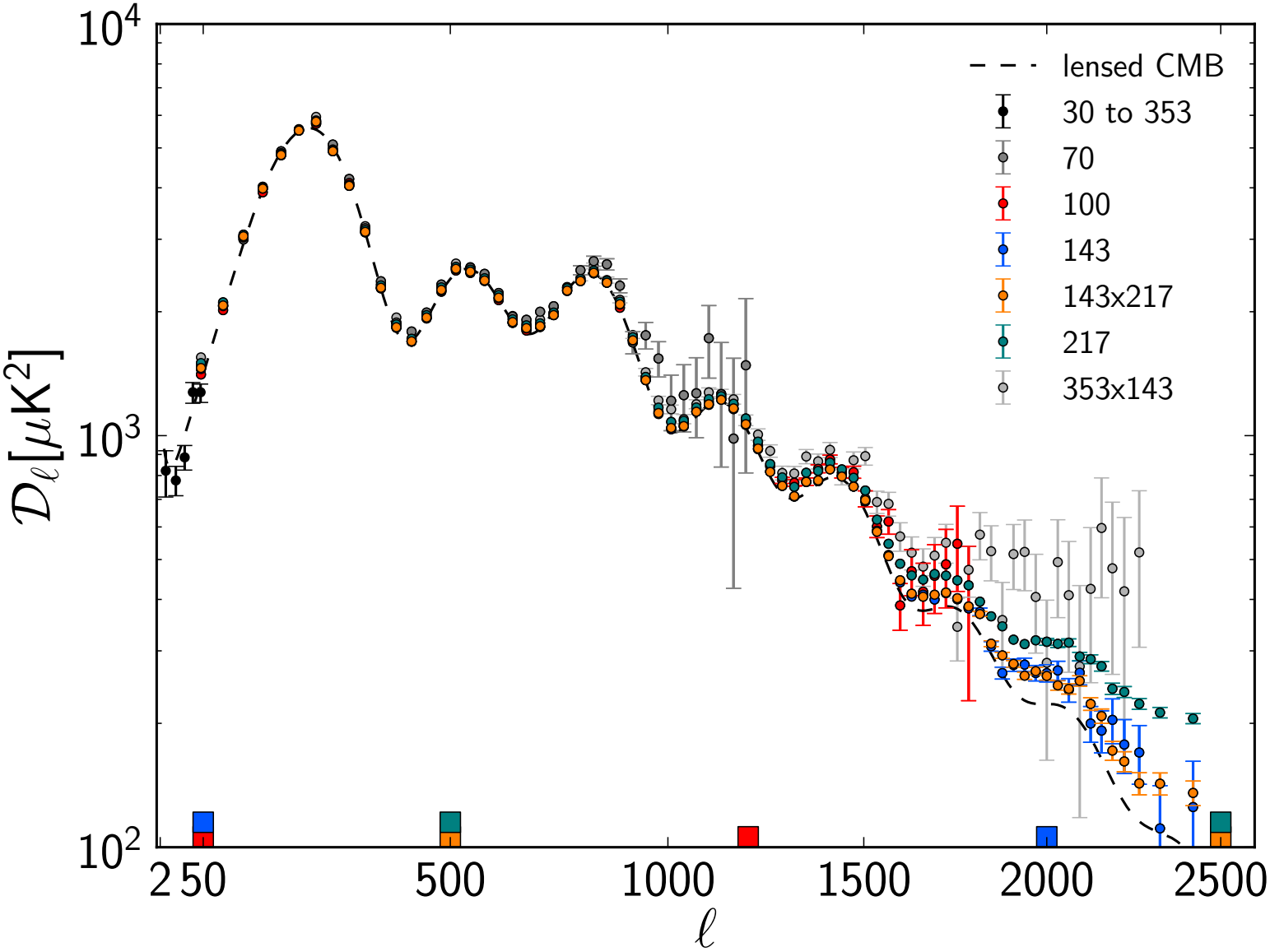
- Minimise foreground impact
  - Spatially
  - In multipole space
  - Keeping low cosmic variance
- Galaxy: 353 GHz thresholding
- Sources: 100-353 GHz catalog

Spectrum	Multipole range	Mask
100×100	50 – 1200	CL49
143×143	50 – 2000	CL31
143×217	500 – 2500	CL31
217×217	500 – 2500	CL31
Combined	50 – 2500	CL31/49

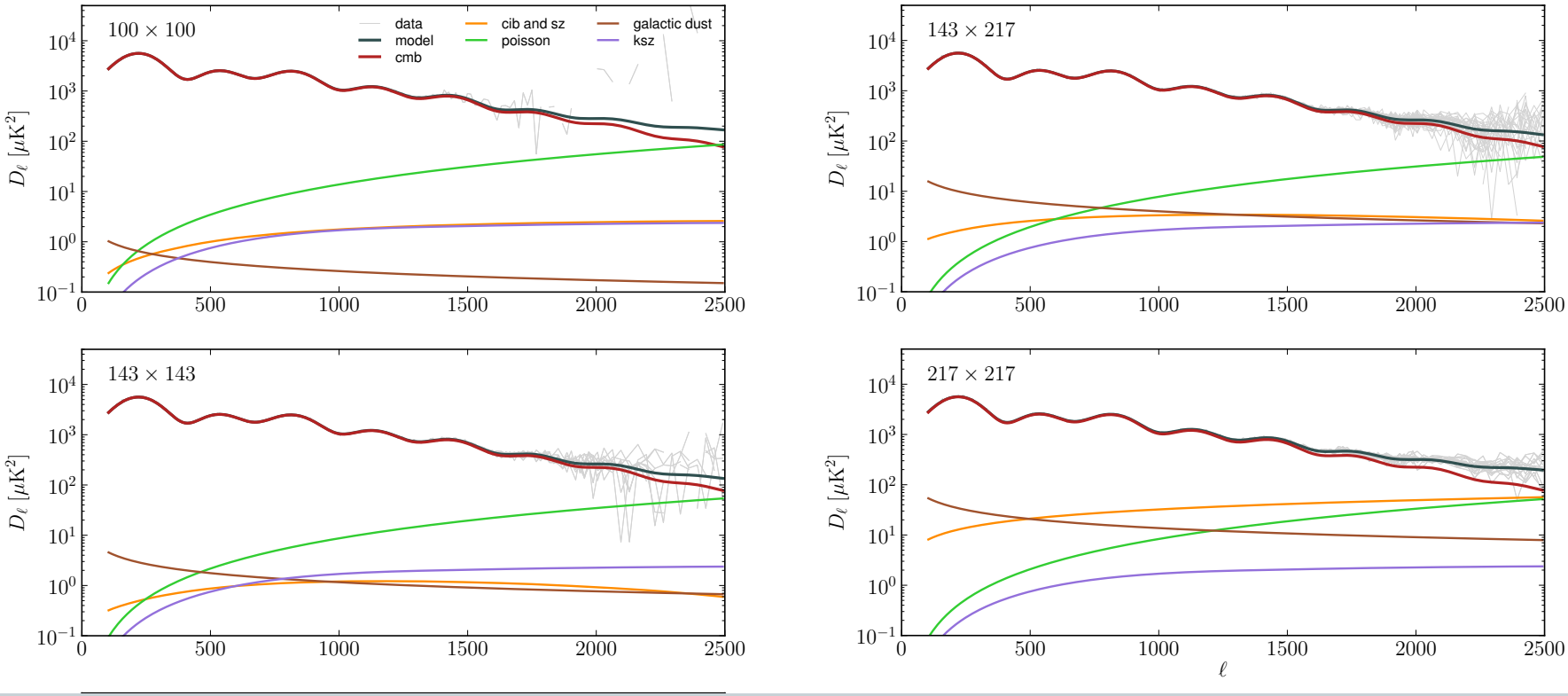


Galactic and sources apodised masks

Planck power spectra

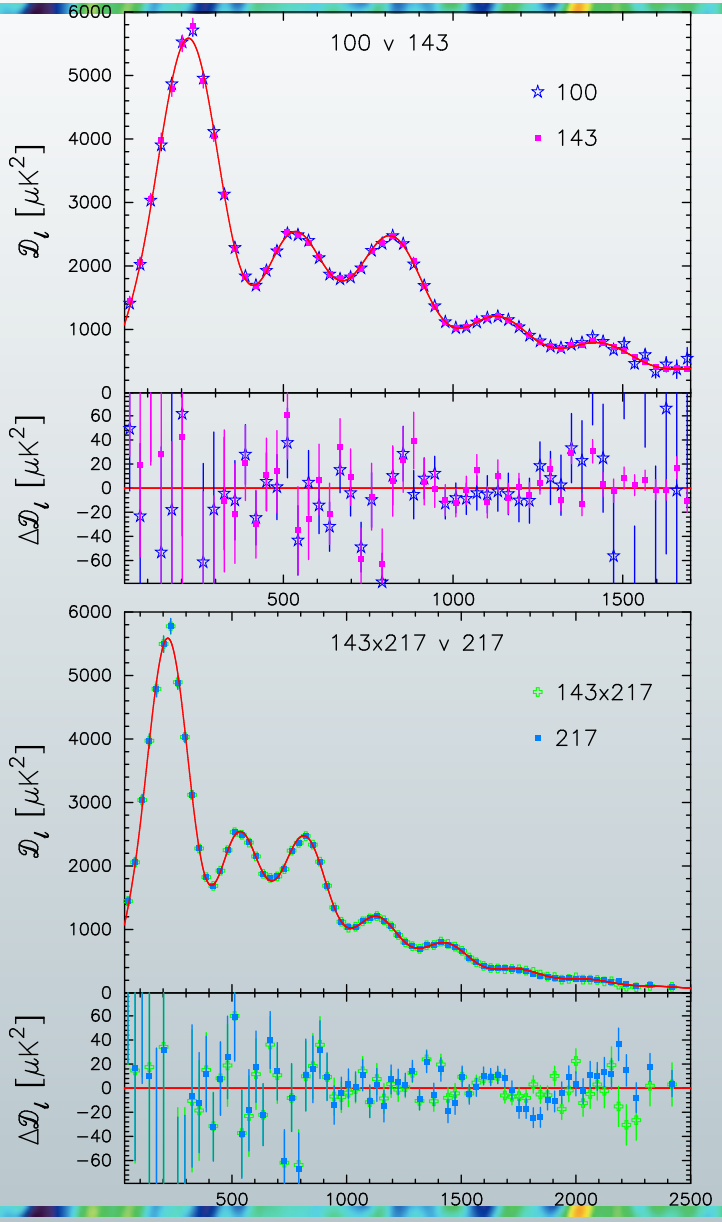


Model decomposition

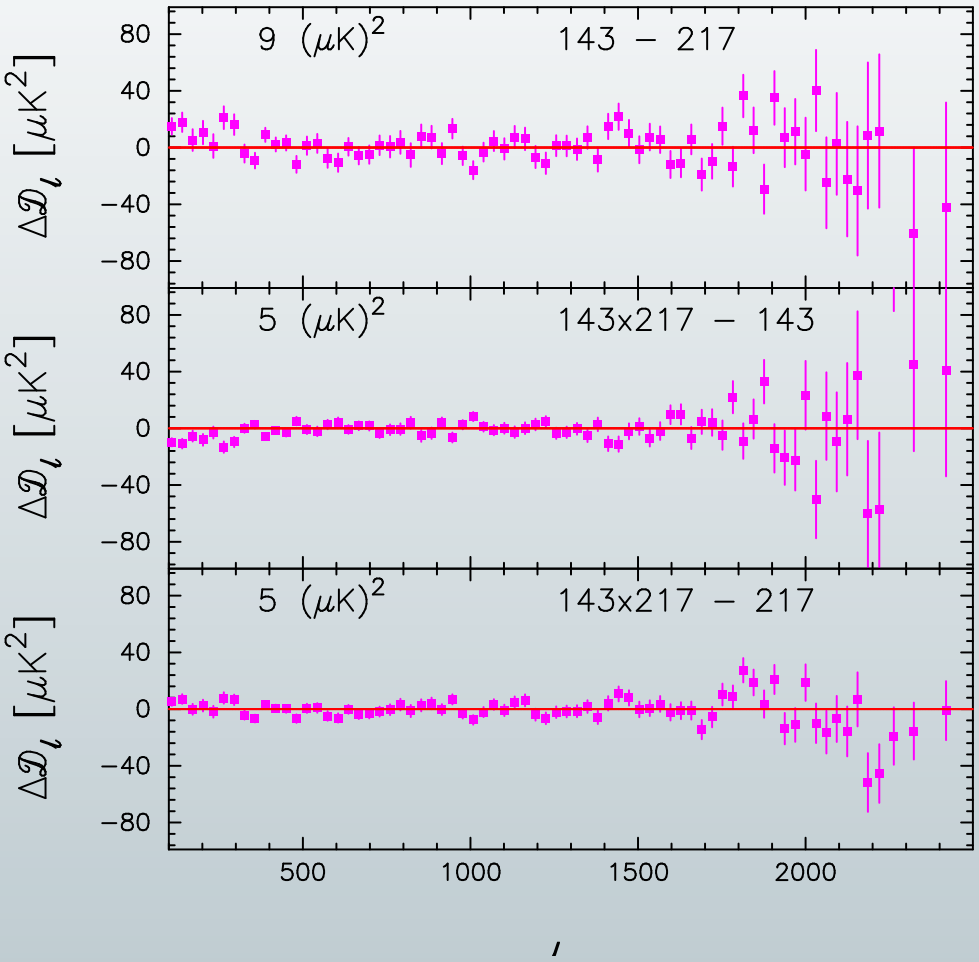


Using here a simplified HL likelihood on binned spectra

HL: internal consistency

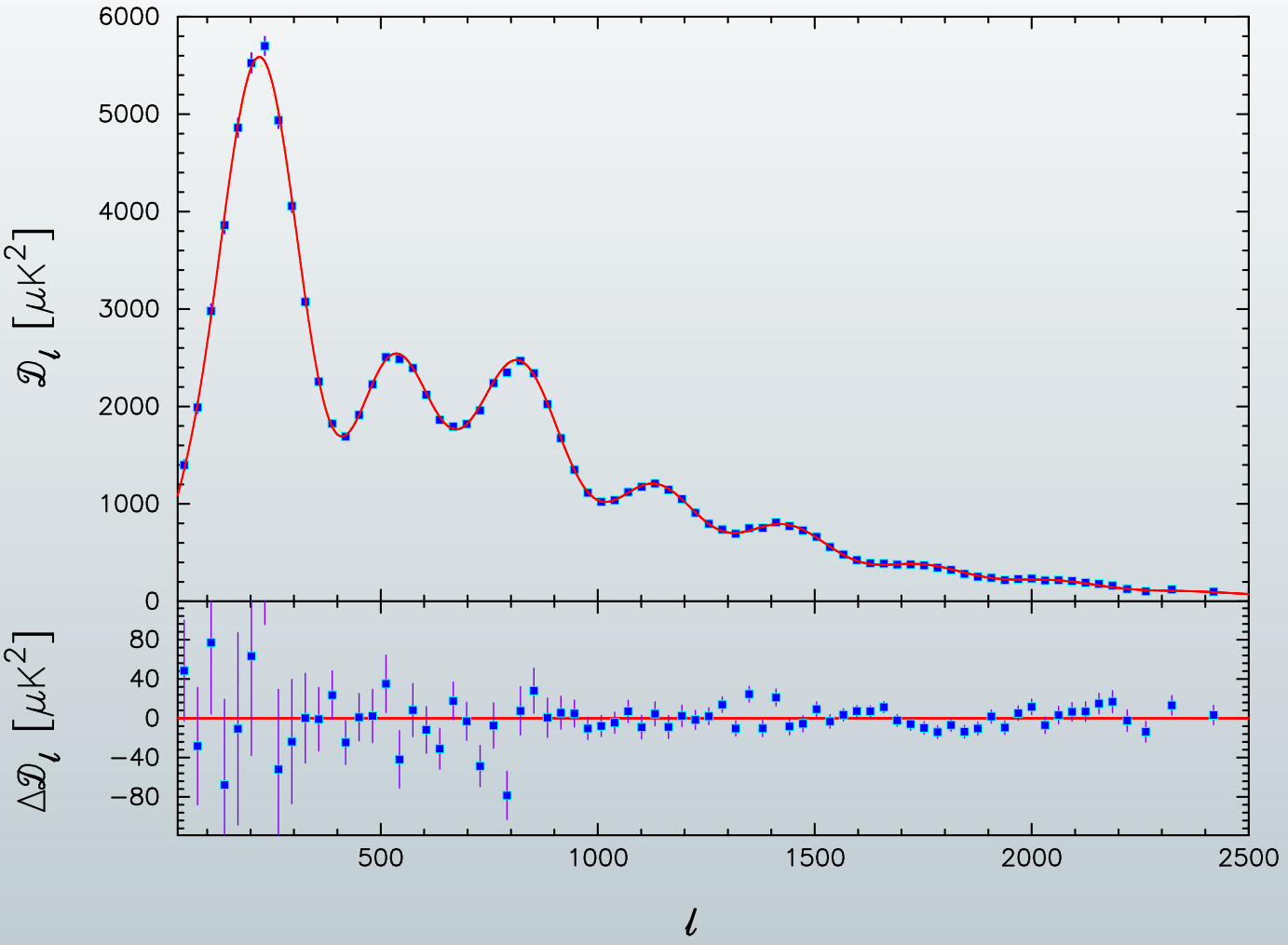


HL: internal consistency

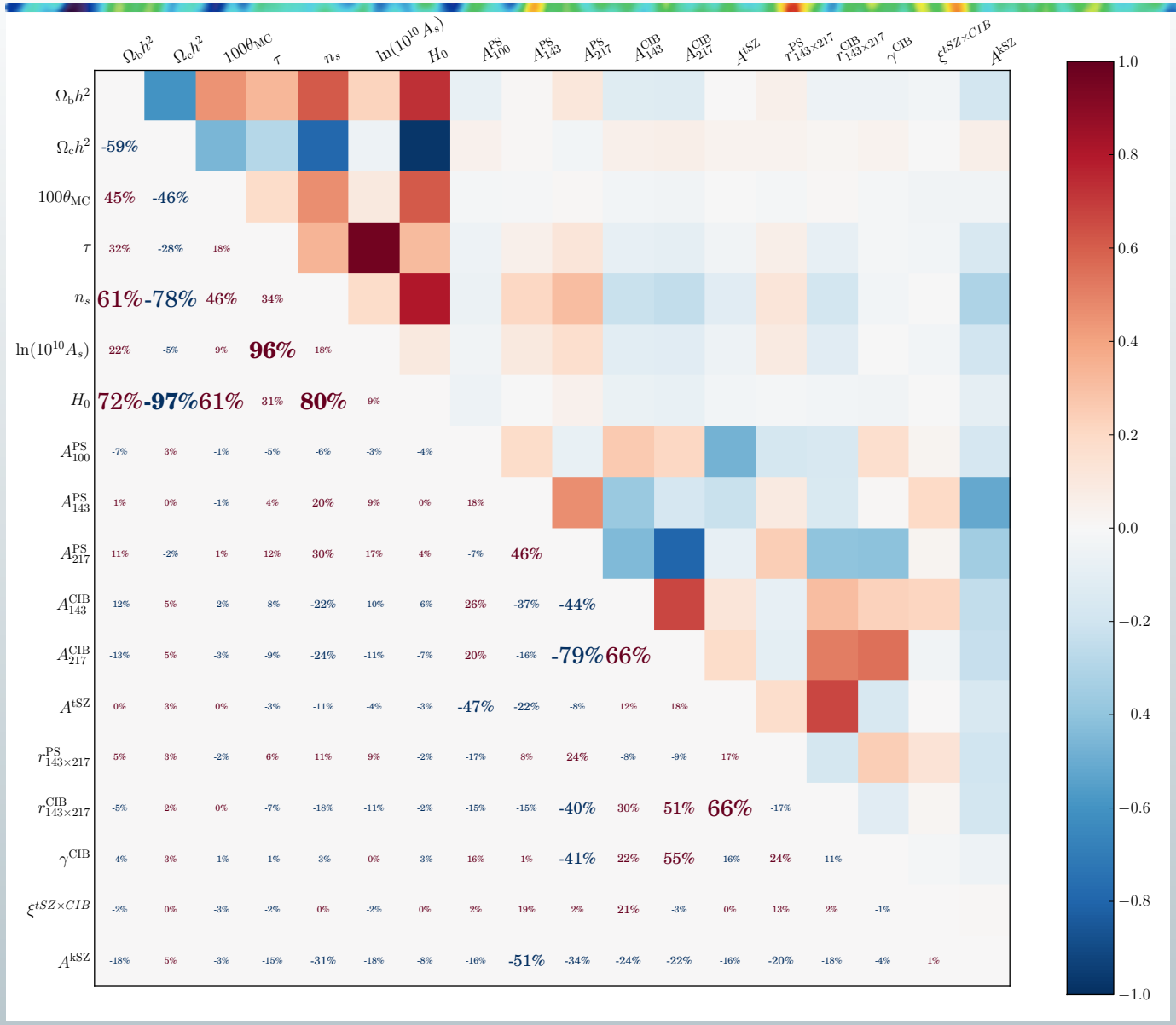


- CMB-induced cosmic variance removed
- Compatible with expected levels of CMB-FG chance correlations

HL: CMB power spectrum



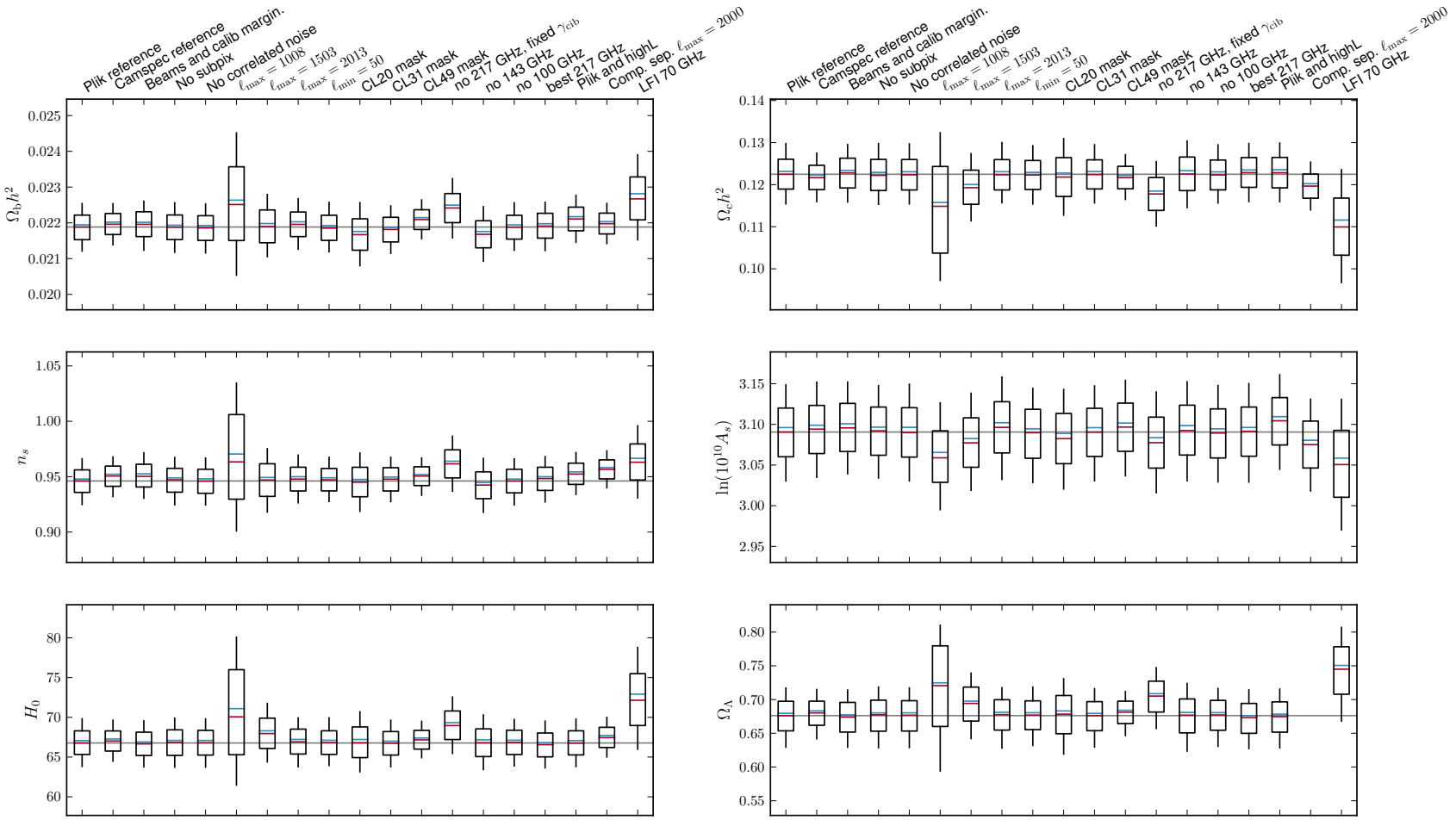
HL posterior correlations



HL posterior correlations

NB: H0 derived parameter

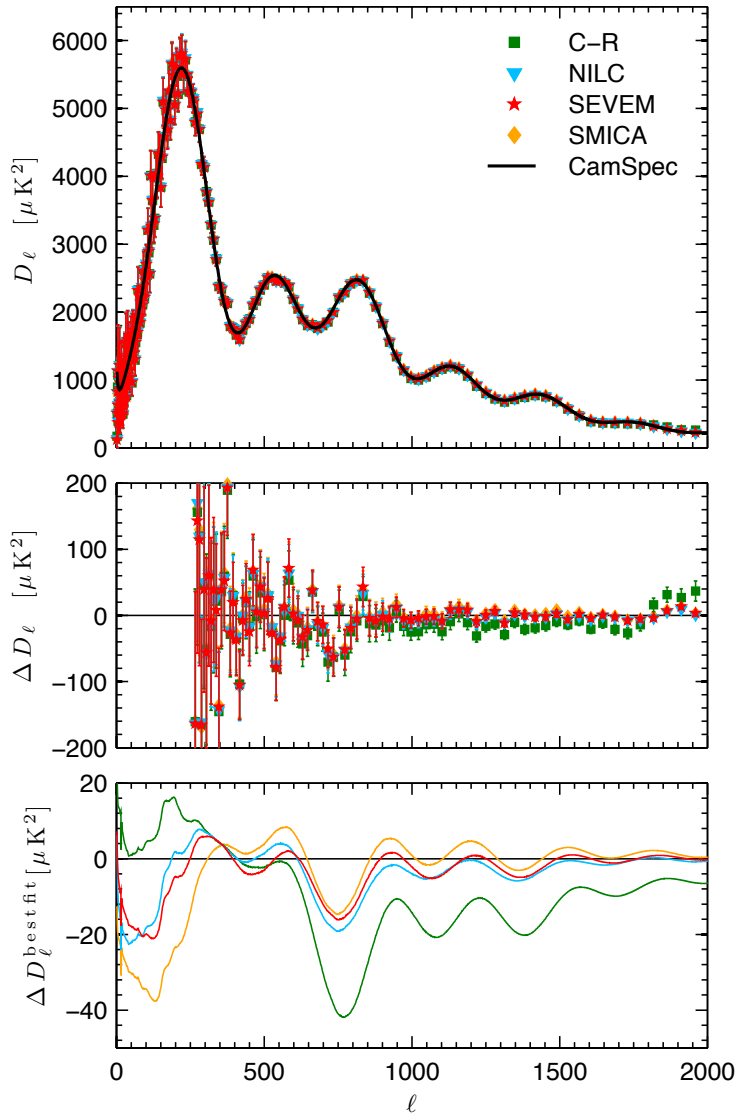
HL: validation test suite



Median, mean, box=68%, line=95%

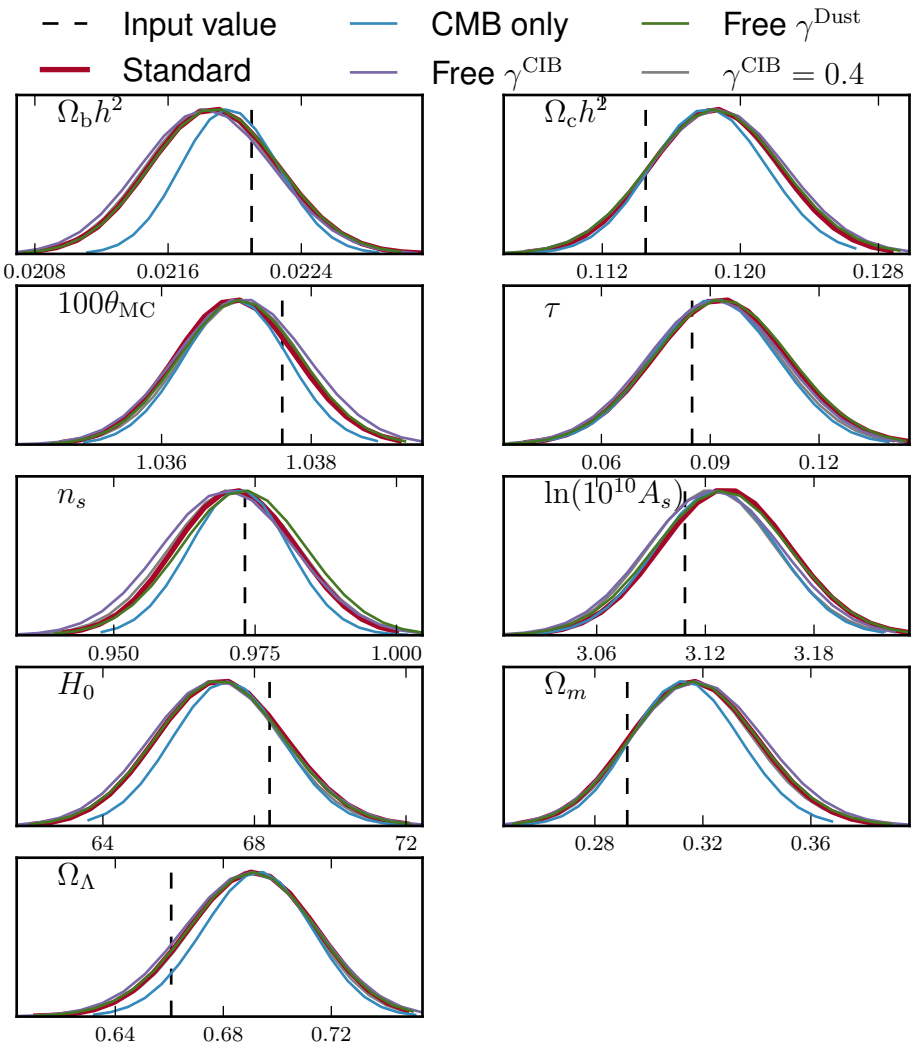
Using simplified, binned HL likelihood, and PICO

Comparison to foreground-cleaned maps



- 4 component separation methods
- 4 Foreground cleaned maps
- Fiducial gaussian likelihood
- 2 parameters for extragalactic FGs
- Multipoles: [2,2000]

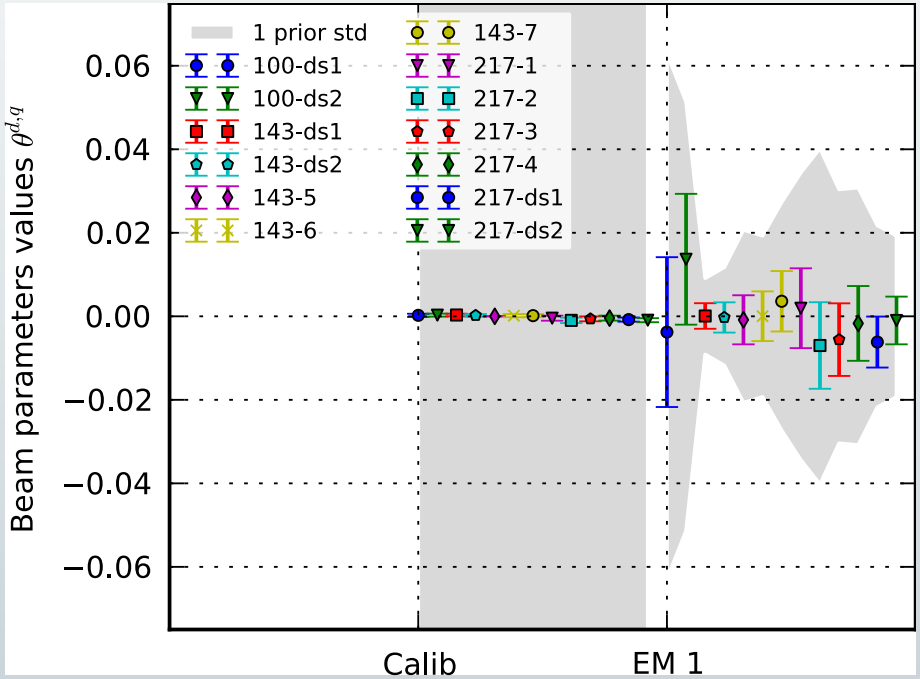
HL: tests on simulated data



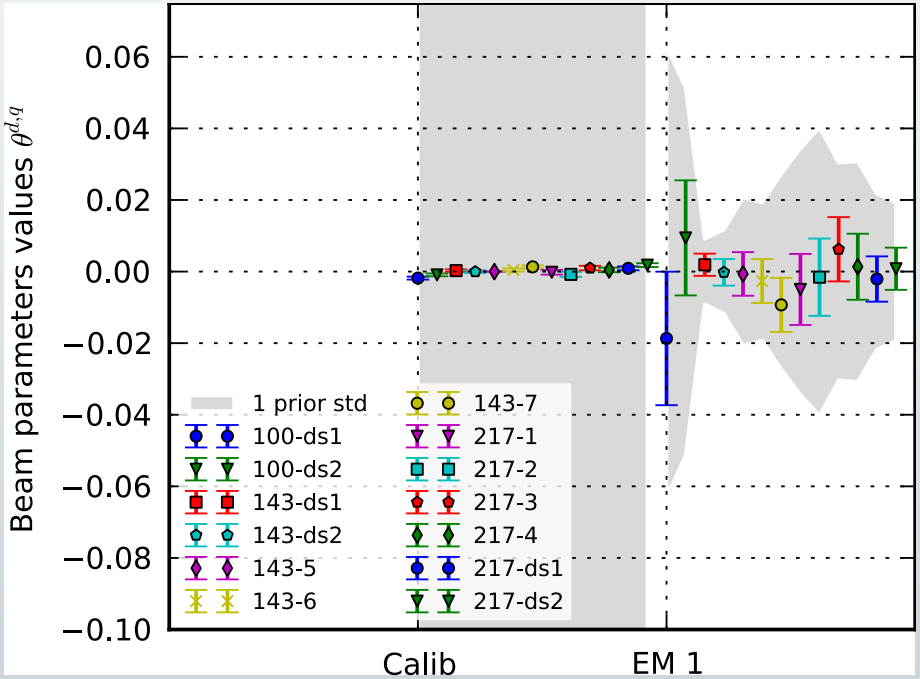
- Full focal plane simulation
- Instrumental complexity:
  - Beam asymmetry
  - Correlated noise
  - Scanning
- Signal complexity:
  - Galactic emissions
  - Extragalactic FGs, resolved and unresolved

HL: tests on simulated data (2)

Simulated data



Planck data

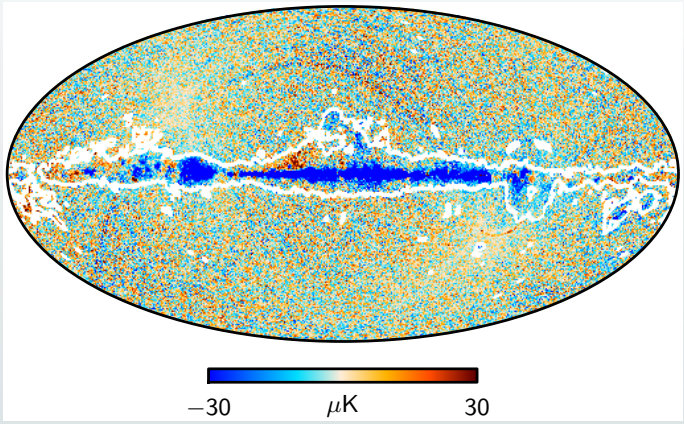


Recalibration < 0.2% in line with dipole based calibrations
Using simplified, binned HL likelihood

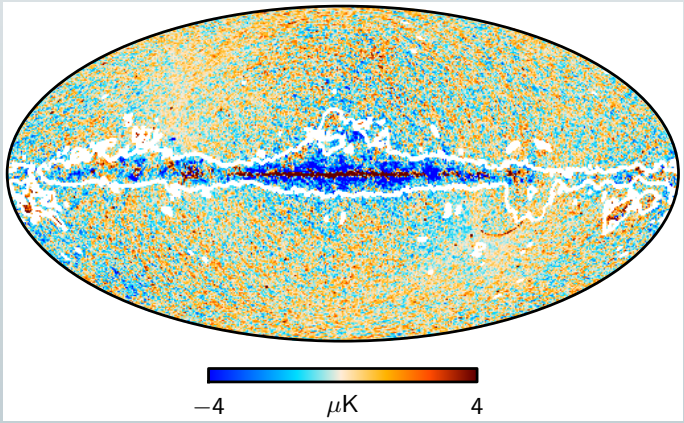
LL specific methodology

- 30-353 GHz frequency maps at low resolution (40')
- Multipole range: [2,49], sharp transition with HL
- Signal model (maps):
  - CMB (1 map)
  - Single low-frequency Galactic component (2 maps)
  - 1 CO component (1 map)
  - 1 dust component (2+ maps)
- Gibbs sampling marginalisation of foreground intensity and spectral parameters maps
- Blackwell-Rao estimate of posterior on individual TT Cls
- Approx. separation of temperature and polarisation:
  - Assume negligible noise in TT, TQ, TU, vanishing B modes
  - Use of WMAP 9 years likelihood, with Planck CMB T map
- Extensive tests on FFP simulations

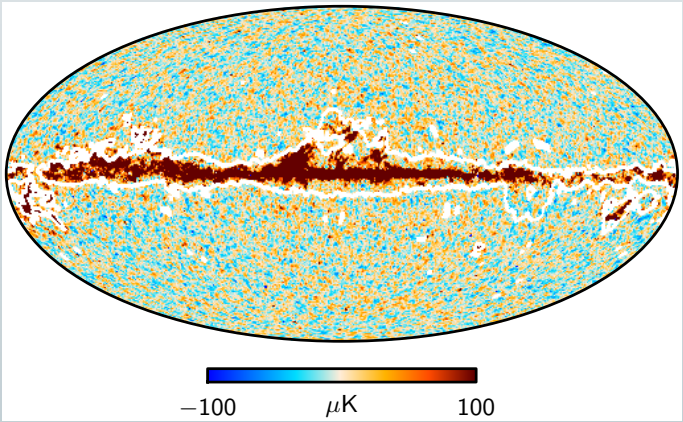
LL mask design and validation



(a) Low-frequency component residual at 30 GHz



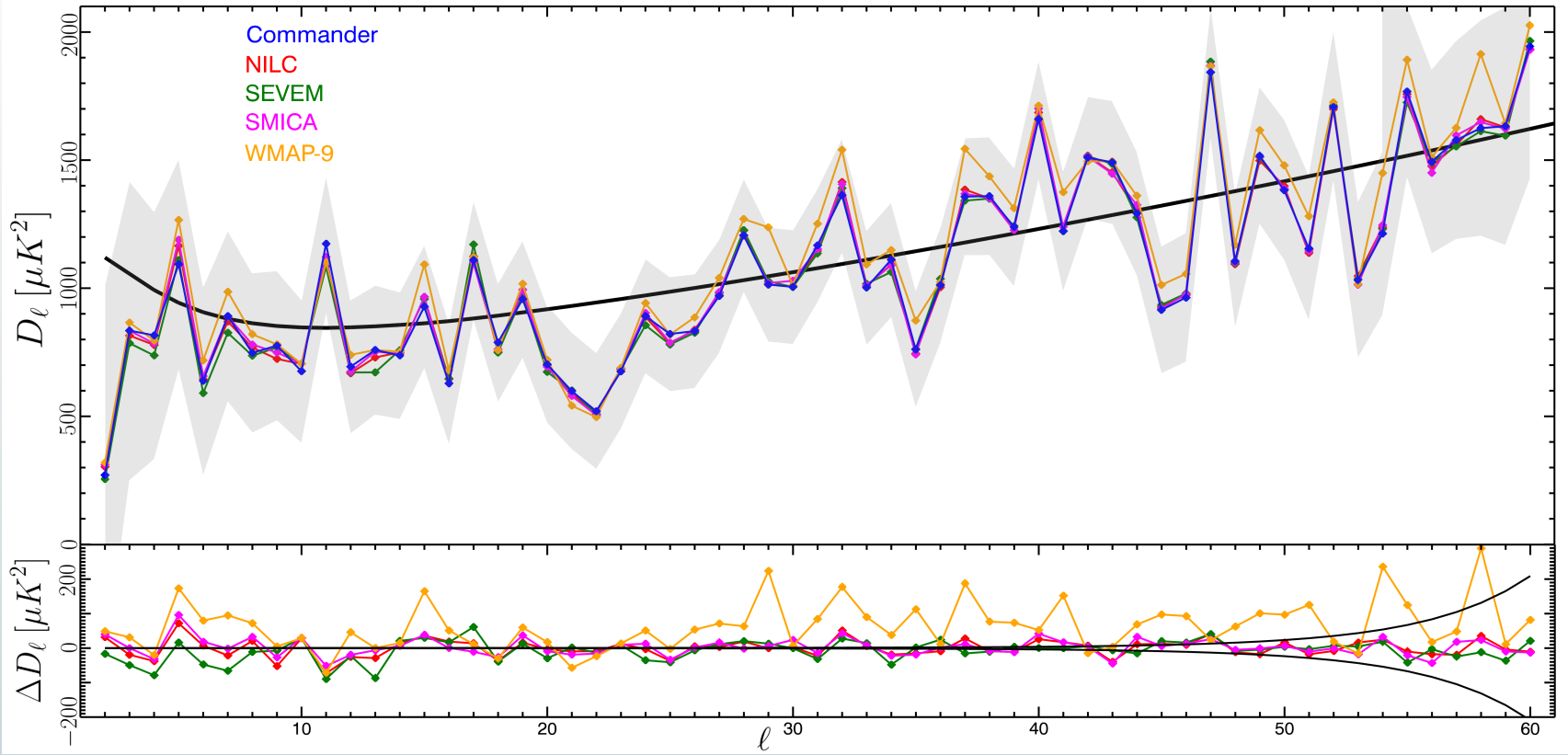
(b) CO residual at 100 GHz



(c) Thermal dust residual at 353 GHz

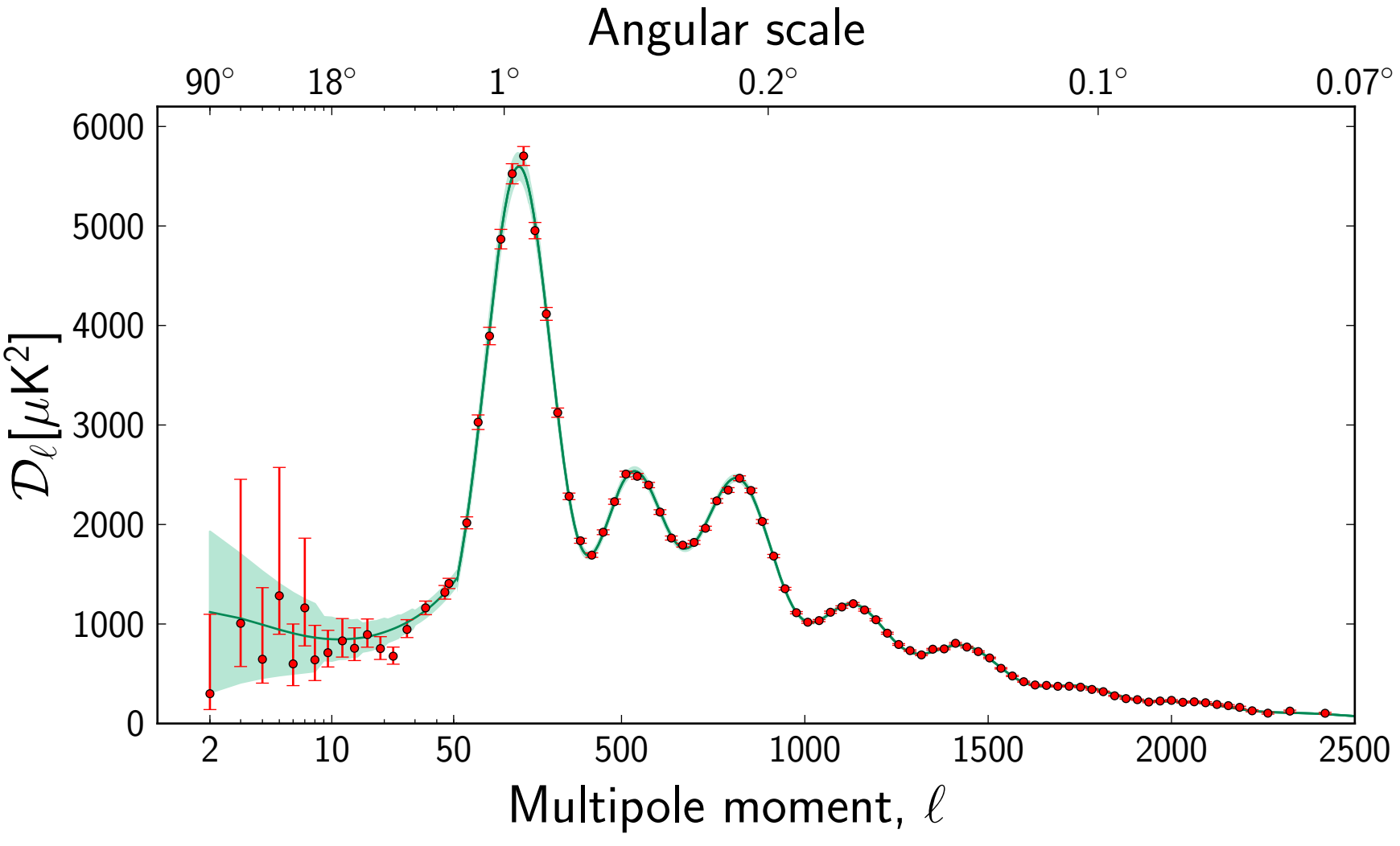
- Thresholding on:
  - Foreground components
  - Residual χ^2 map
- 87% sky coverage (L87)
- Validated on FFP simulations

LL power spectra



- Based on the CS U78 union mask
- Same features as in the WMAP-9 spectrum
- Robustness with component separation method

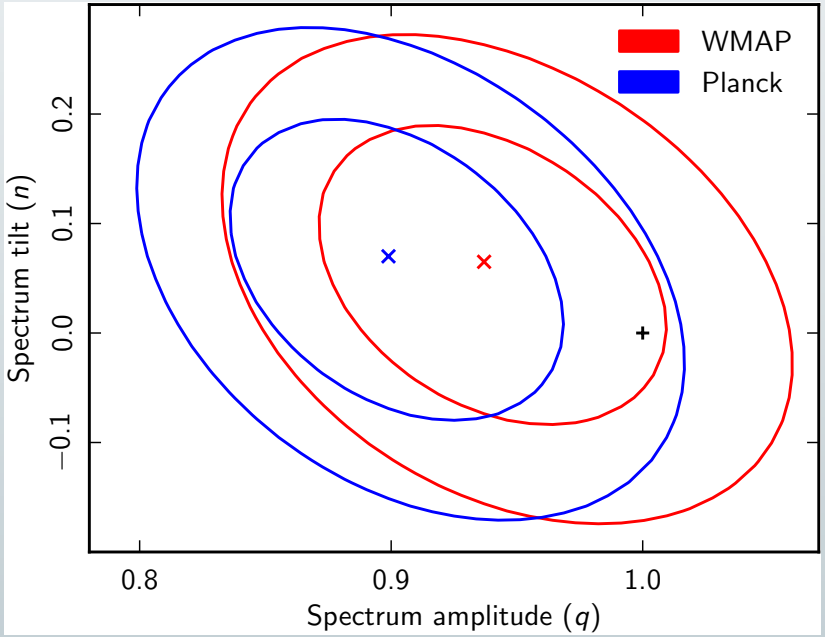
Planck CMB power spectrum



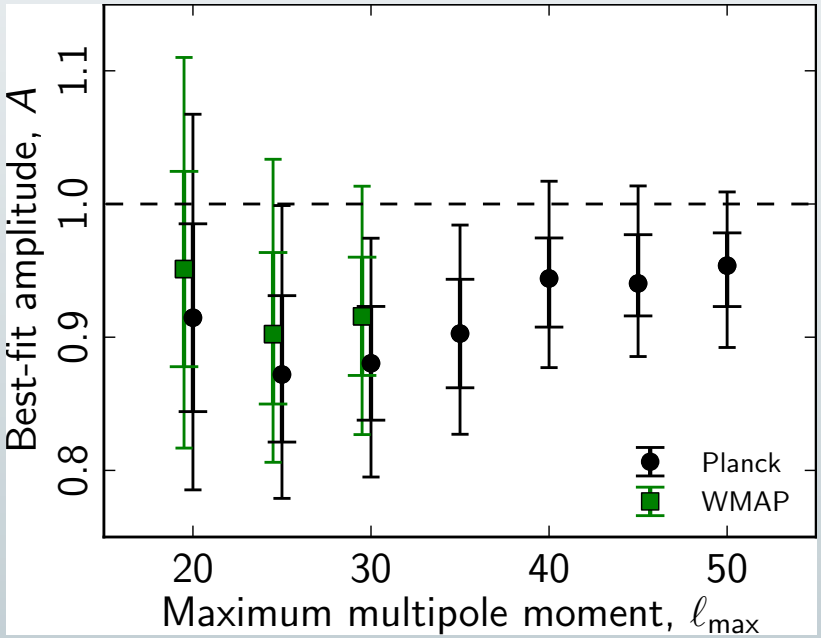
Model tension at low multipoles ?

Planck best fit model, with extra amplitude and tilt

$\ell_{\max} = 30$



Marginalized over tilt



Thank you.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NASA
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DTU Space
National Space Institute
Science & Technology Facilities Council
CSIC
National Research Council of Italy
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MINISTERIO DE CIENCIA E INNOVACIÓN
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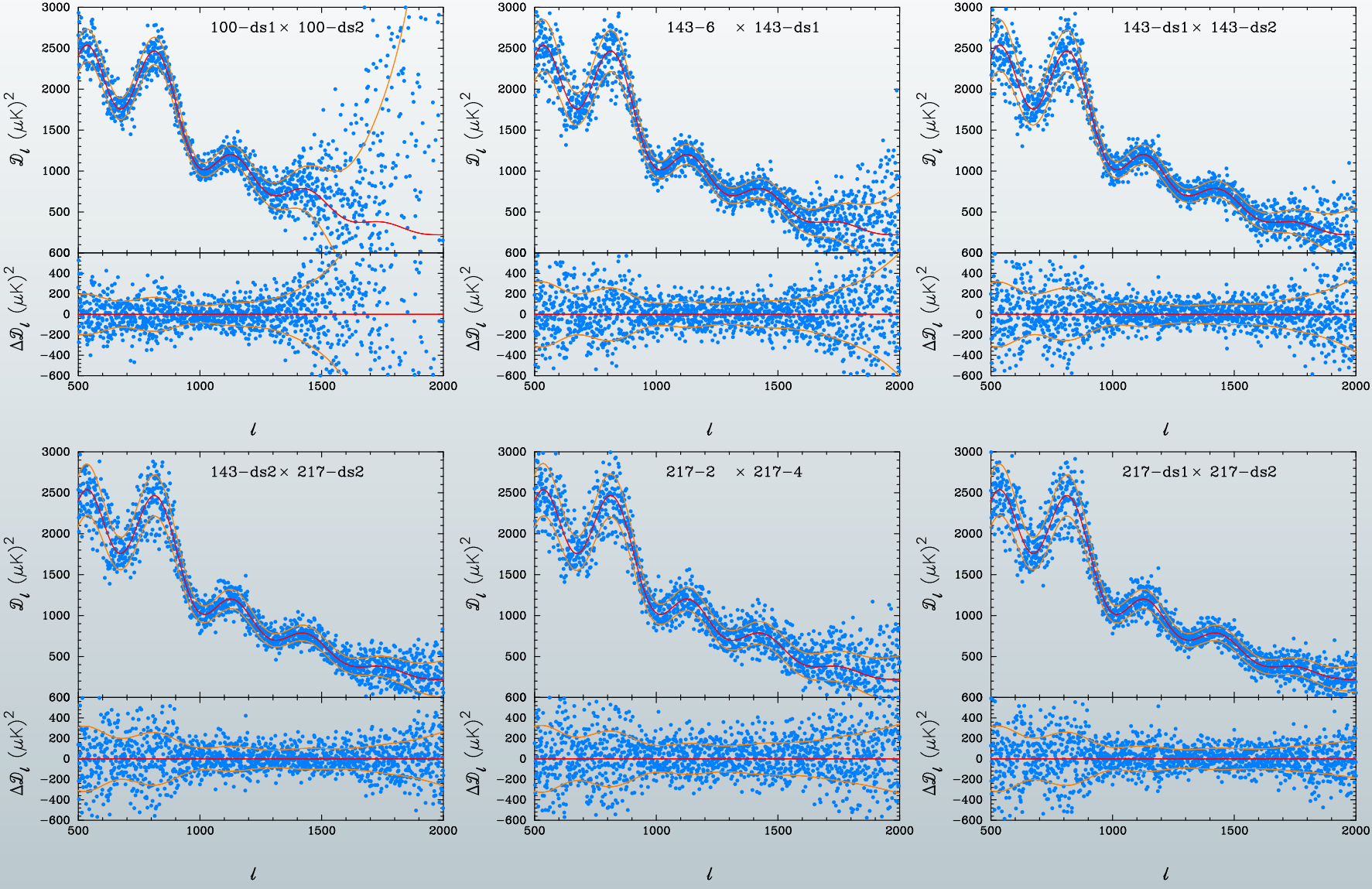
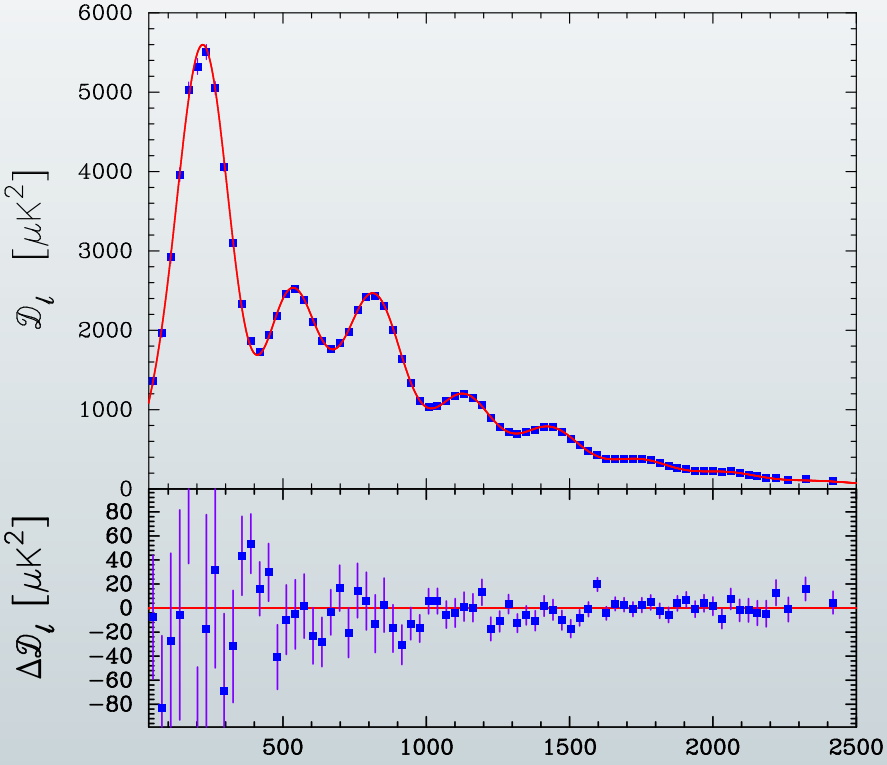
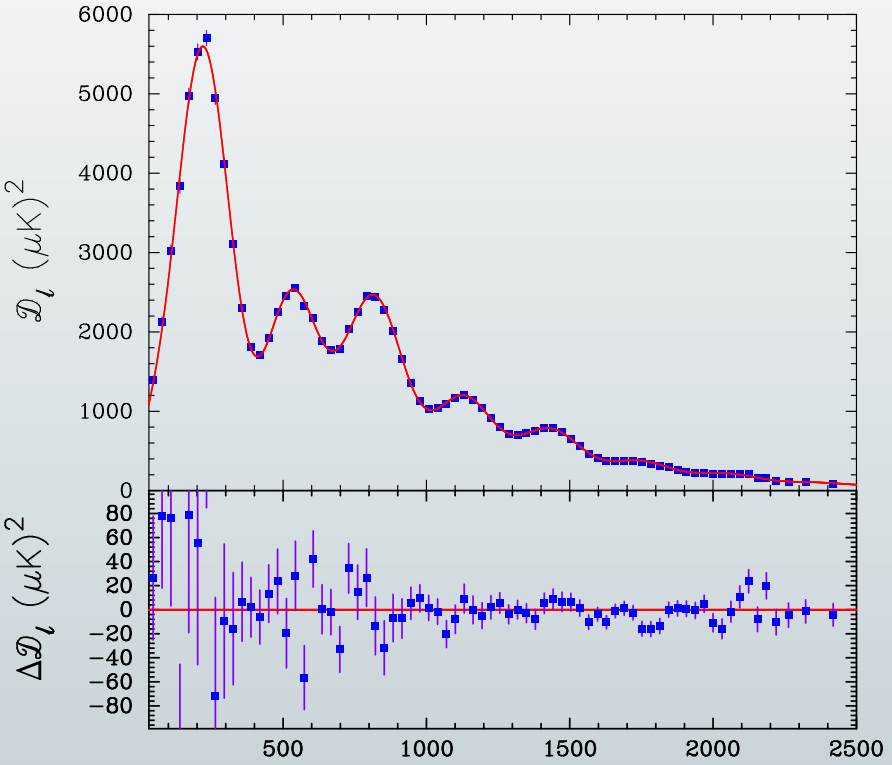
A selection of foreground-subtracted spectra



Correlated error modes





Examples of simulated spectra, using HL covariance