Correlations between Cosmic Ray and Maps of WMAP and Planck

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WMAP: each pixel 0.11°x0.11°

Temperature Q

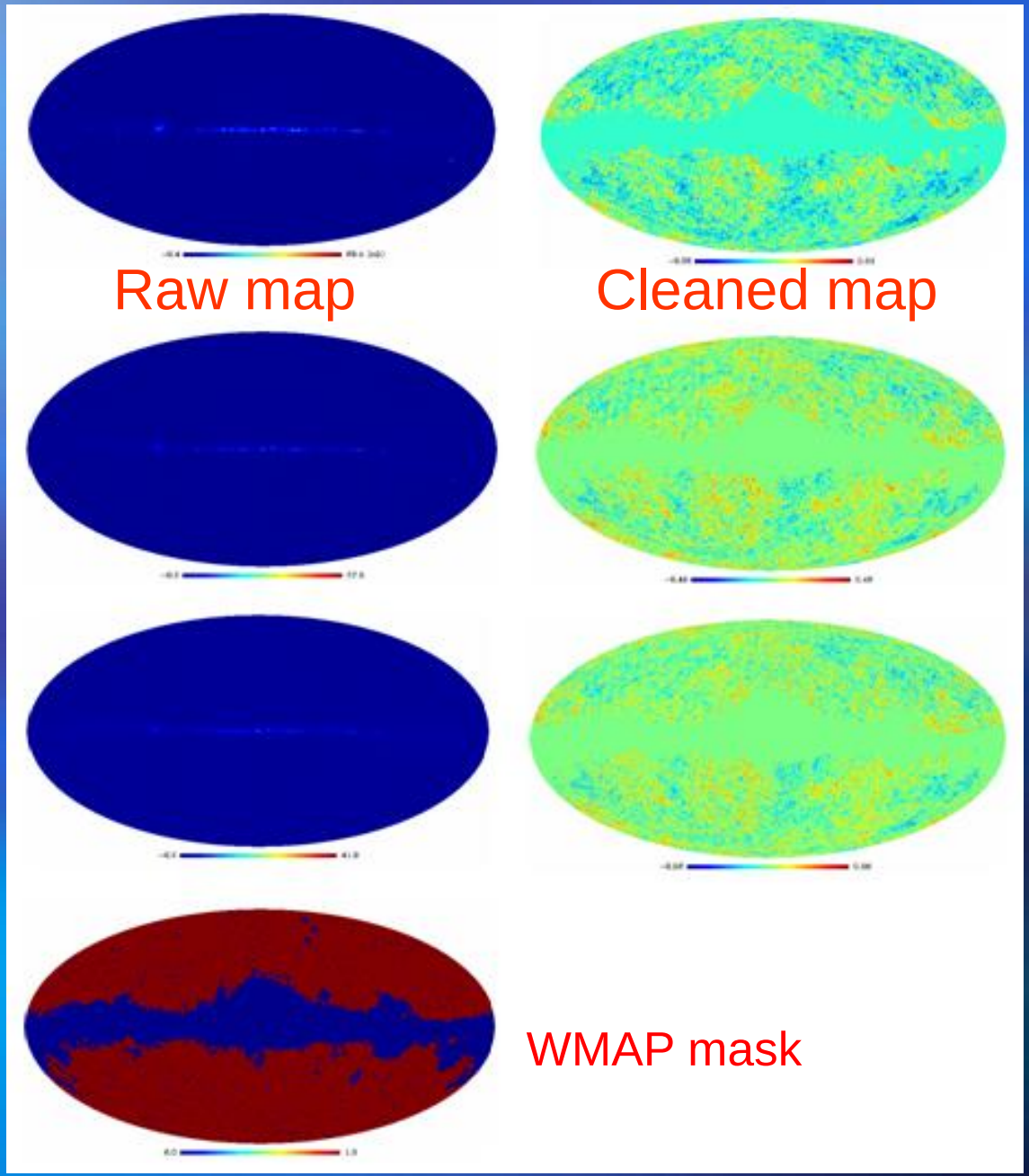
41 GHz

Temperature V

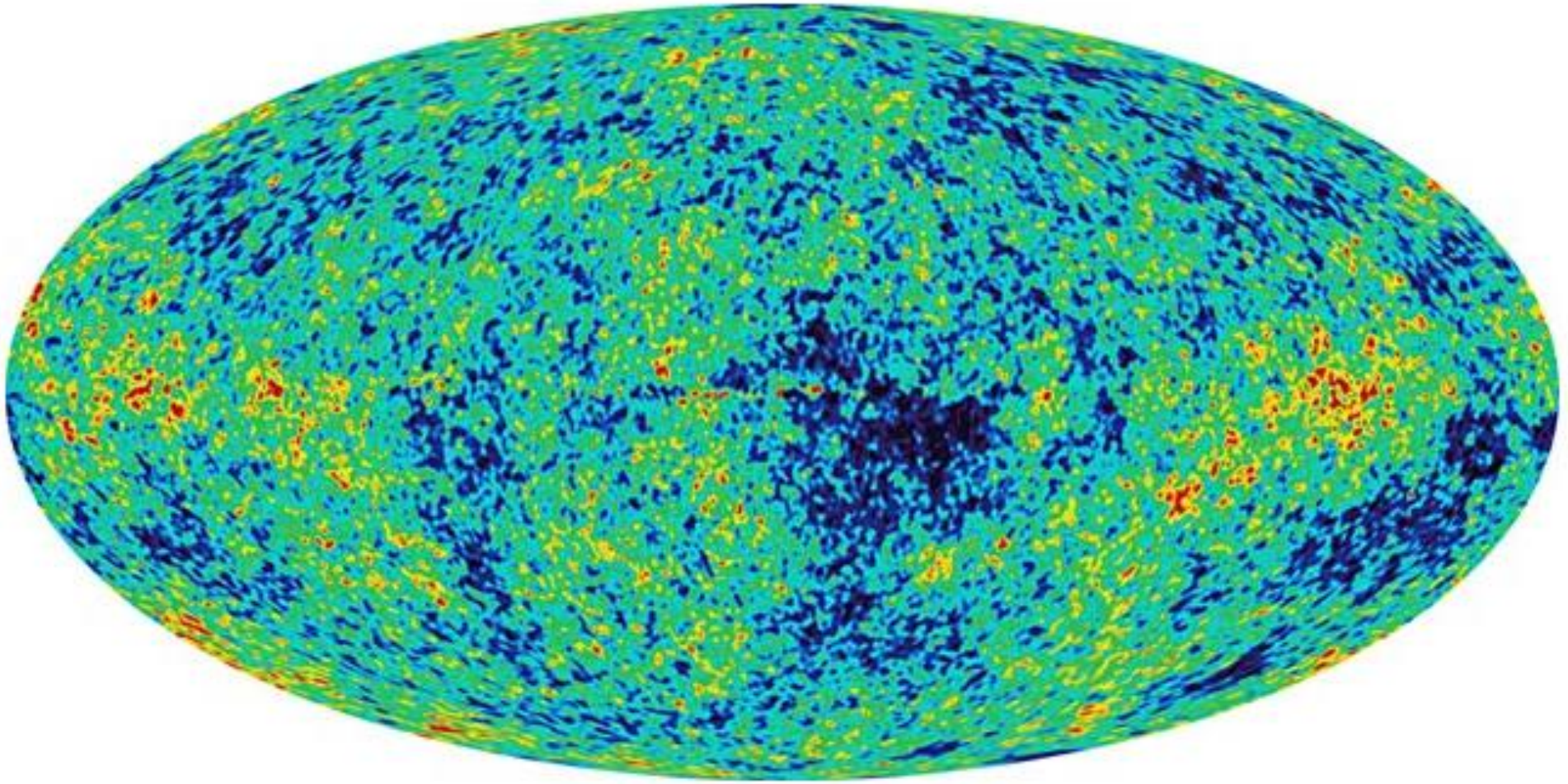
61 GHz

Temperature W

94 GHz



How clean is the “cleaned” map?



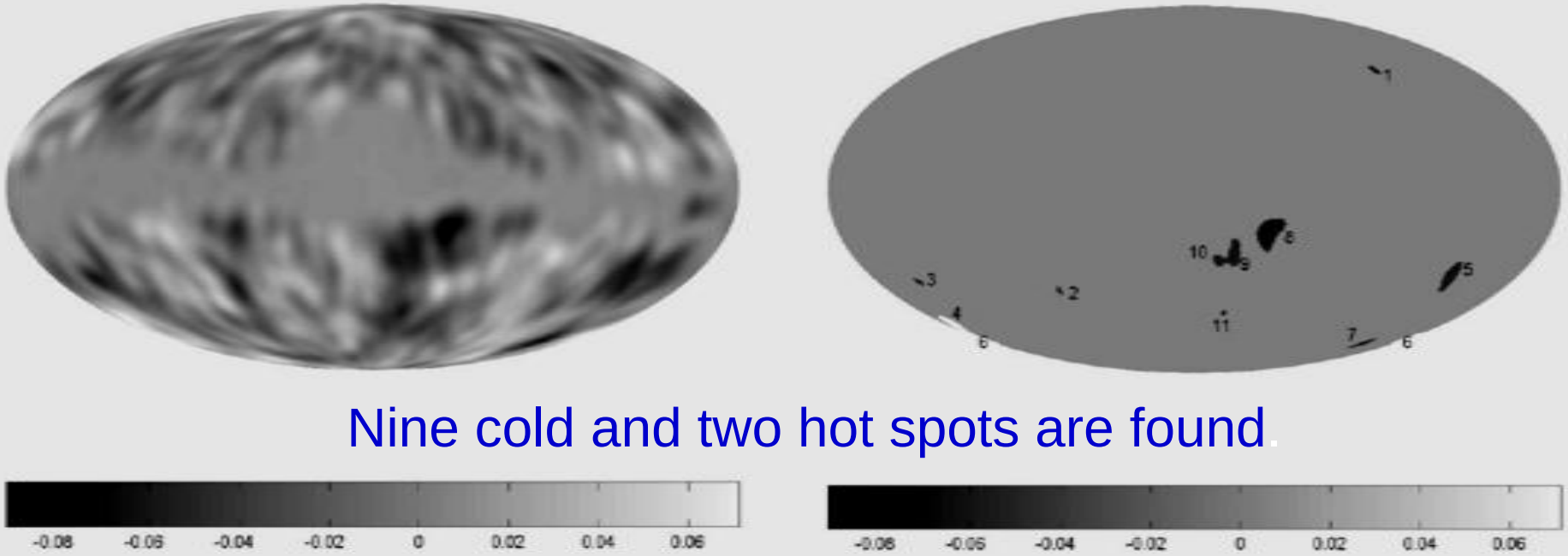
THE ASTROPHYSICAL JOURNAL, 633:542–551, 2005 November 10

Liu, X., Zhang, SN, ApJ, 2005, 633:542

NON-GAUSSIANITY DUE TO POSSIBLE RESIDUAL FOREGROUND SIGNALS IN *WILKINSON MICROWAVE ANISTROPY PROBE* FIRST-YEAR DATA USING SPHERICAL WAVELET APPROACHES

XIN LIU[1] AND SHUANG NAN ZHANG[1,2,3,4]

Received 2004 December 18; accepted 2005 April 26



Nine cold and two hot spots are found.

FIG. 3.—Inverse spherical wavelet transformed and 3 σ thresholded Q-V-W–combined *WMAP* maps in real space.

THE ASTROPHYSICAL JOURNAL, 636:L1–L4, 2006 January 1

A CROSS-CORRELATION ANALYSIS OF *WMAP* AND EGRET DATA IN WAVELET SPACE

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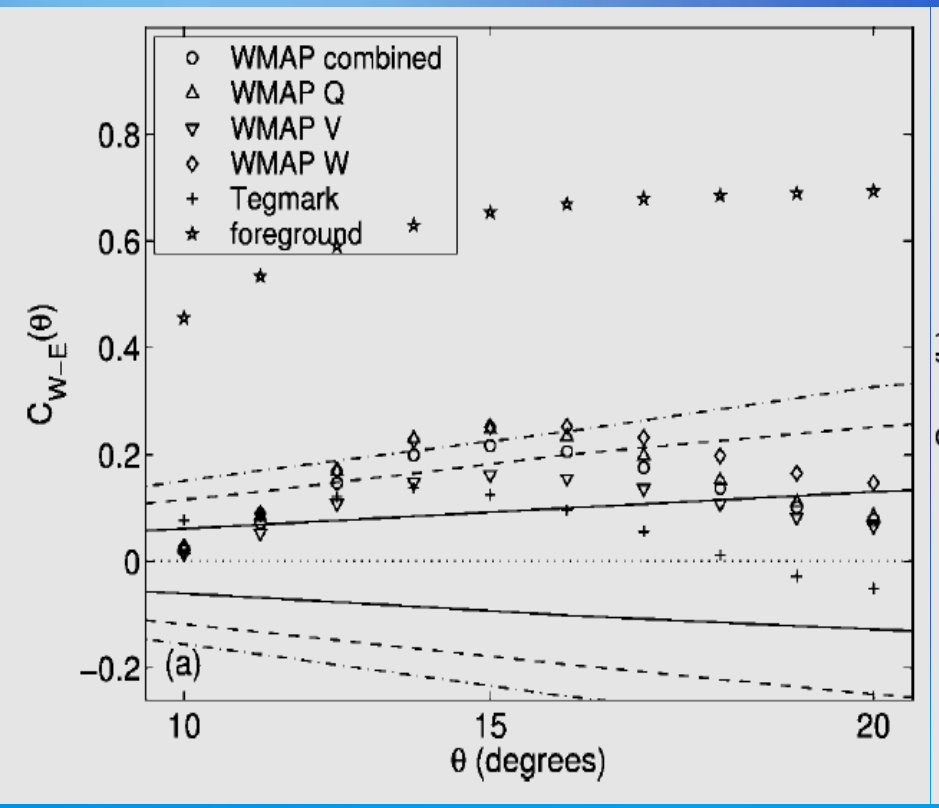

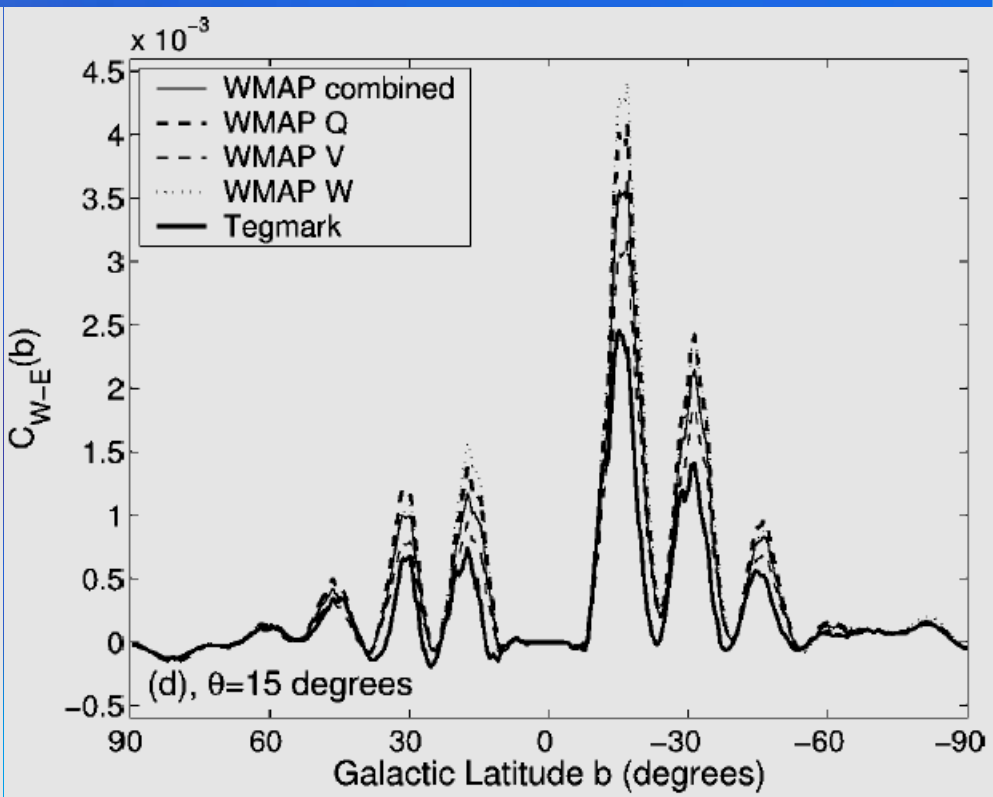

Clear signature of Galactic origin

Liu, X., Zhang, SN, ApJL, 2006, 636:L1

Chin. J. Astron. Astrophys. Vol. 7 (2007), No. 2, 199–208
(*http://www.chjaa.org*)

Chinese Journal of Astronomy and Astrophysics

Cross-Correlation Detection of Point Sources in the WMAP First Year Data *

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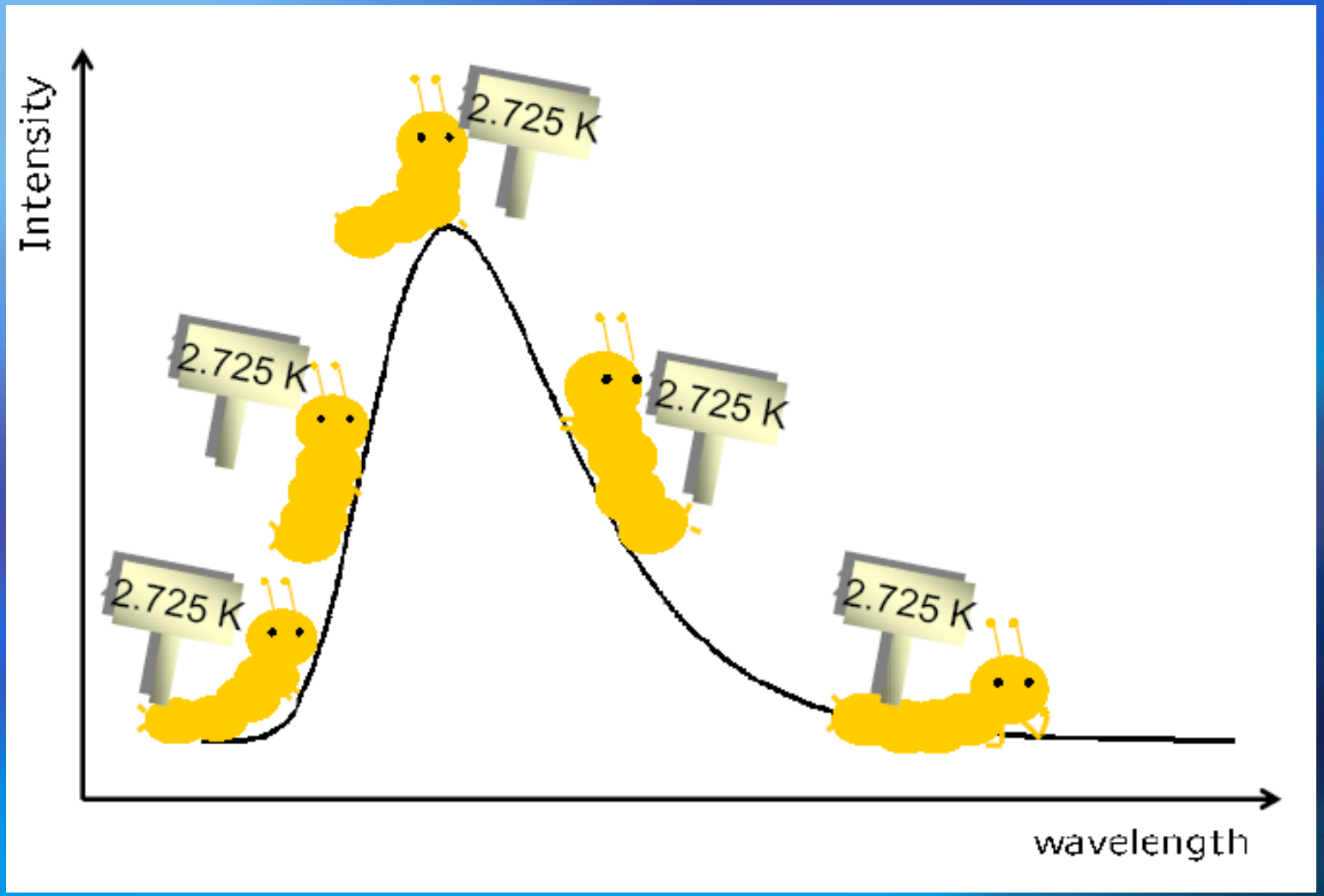
Abstract We apply a Cross-Correlation (CC) method developed previously for detecting gamma-ray point sources to the WMAP first year data by using the Point-Spread Function of WMAP and obtain a full sky CC coefficient map. We find that the CC method is a powerful tool to examine the WMAP foreground residuals which can be further cleaned accordingly. Evident foreground signals are found in the WMAP foreground cleaned maps and the *Tegmark* cleaned map. In this process 101 point sources are detected, and 26 of them are new sources additional to the originally listed WMAP 208 sources. We estimate the flux of these new sources and verify them by another method. As a result, a revised mask file based on the WMAP first year data is produced by including these new sources.

WMAP first year data is produced by including these new sources.

Nie, JY, Zhang, SN, ChJAA, 2007, 7:199

Confirmed by WMAP team (Wright et al. 2008, The Wilkinson Microwave Anisotropy Probe (WMAP) Source Catalog)

Testing the black body nature of WMAP's CMB map



THE ASTROPHYSICAL JOURNAL, 708:375–380, 2010 January 1 doi:10.1088/0004-637X/708/1/375

SIGNIFICANT FOREGROUND UNRELATED NON-ACOUSTIC ANISOTROPY ON THE 1 DEGREE SCALE IN *WILKINSON MICROWAVE ANISOTROPY PROBE* 5-YEAR OBSERVATIONS

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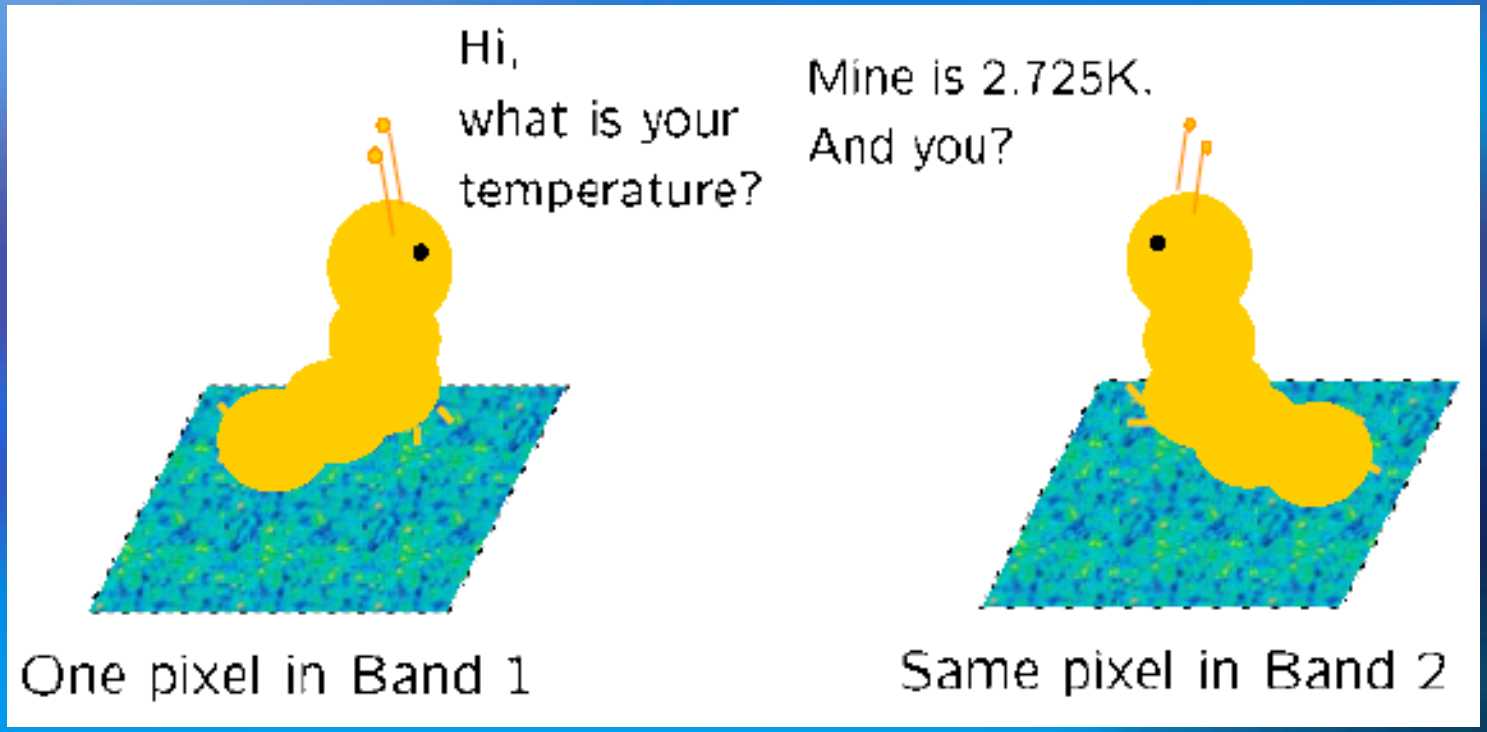
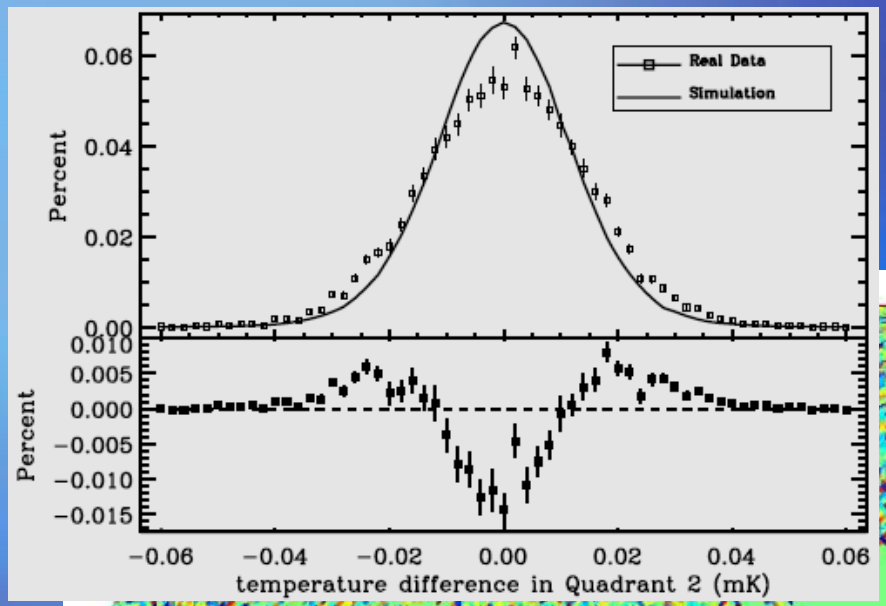
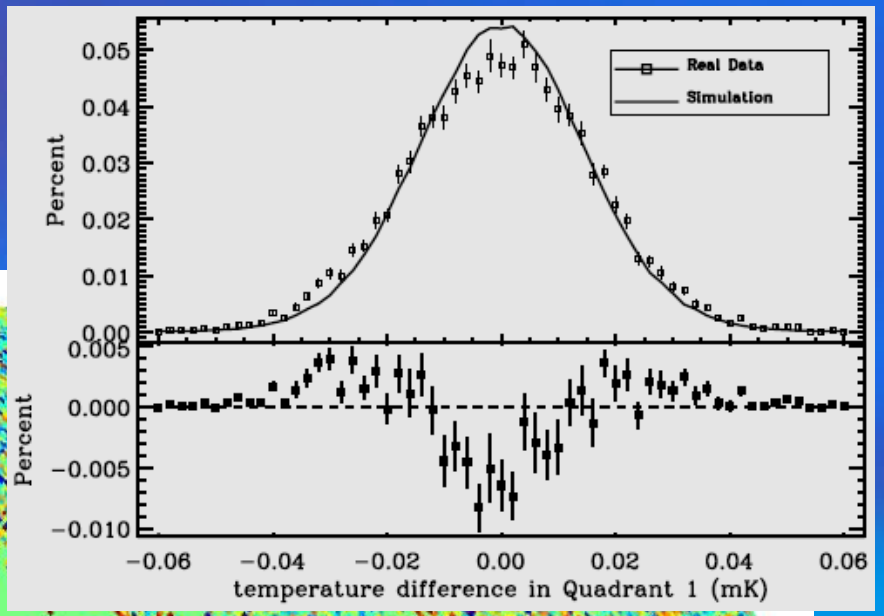
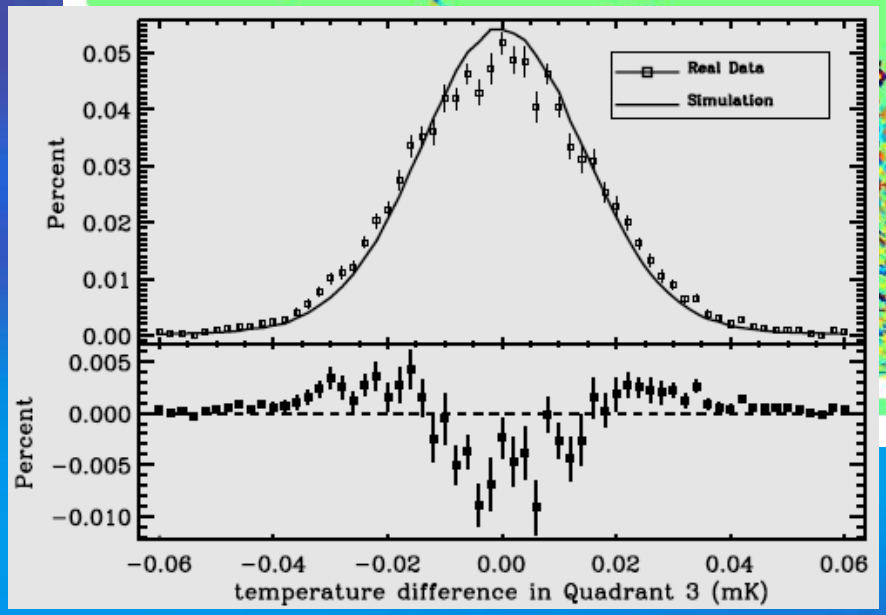


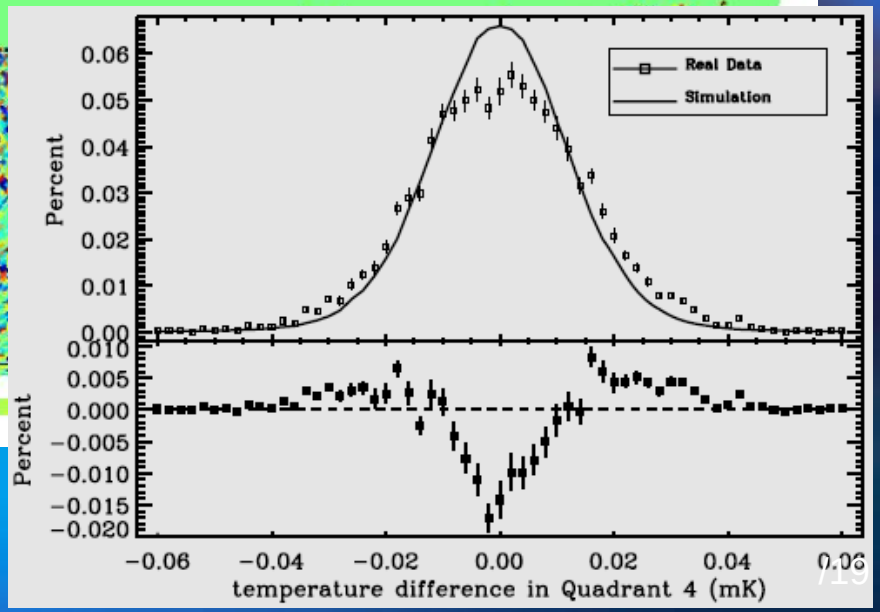
Jiang, BZ, Lieu, R., Zhang, SN, Wakker, B., ApJ, 208:375


Real Data
Simulation
Percent
temperature difference in Quadrant 2 (mK)


Real Data
Simulation
Percent
temperature difference in Quadrant 1 (mK)

V-W map


Real Data
Simulation
Percent
temperature difference in Quadrant 3 (mK)


Real Data
Simulation
Percent
temperature difference in Quadrant 4 (mK)

WMAP's CMB is very close to BB, but?

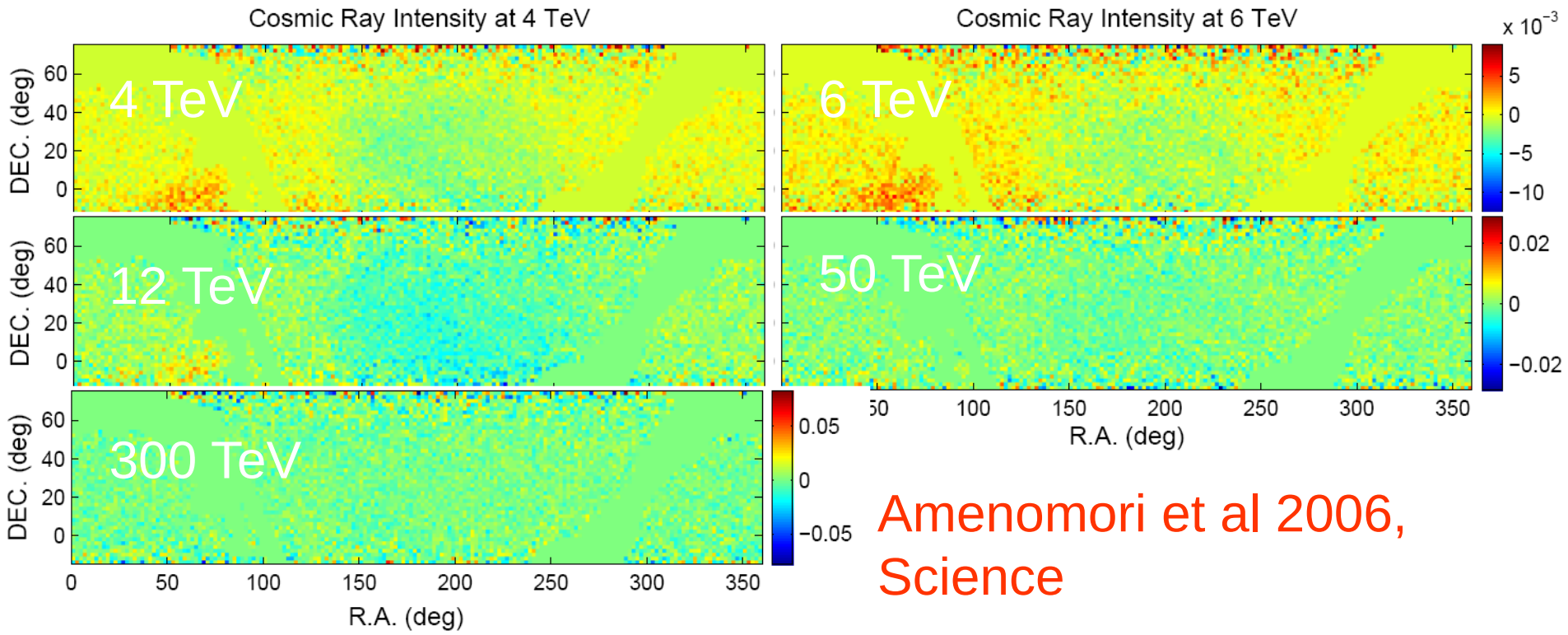
Table 1

Parameters for the Gaussian Curves that Fitted the WMAP5 Data and the Pixel Noise Histograms (The Latter are the Solid Lines) of Figure 2

$V-W$		$\mu(\mu K)$	Error (μK)	σ (μK)	Error (μK)
	WMAP5	−0.23	0.15	16.23	0.13
Quadrant 1	Simulation	0.00	0.13	14.70	0.12
	Difference Δ	−0.23	0.20	6.88	0.40
	WMAP5	0.24	0.12	14.47	0.10
Quadrant 2	Simulation	−0.04	0.12	12.10	0.10
	Difference Δ	0.28	0.17	7.94	0.24
	WMAP5	−0.11	0.16	16.22	0.13
Quadrant 3	Simulation	0.03	0.15	14.70	0.12
	Difference Δ	−0.14	0.22	6.86	0.40
	WMAP5	0.40	0.13	14.80	0.10
Quadrant 4	Simulation	−0.01	0.13	12.26	0.10
	Difference Δ	0.41	0.18	8.30	0.23

The residual fluctuations represents an unexplained non-blackbody signal: some systematic errors?

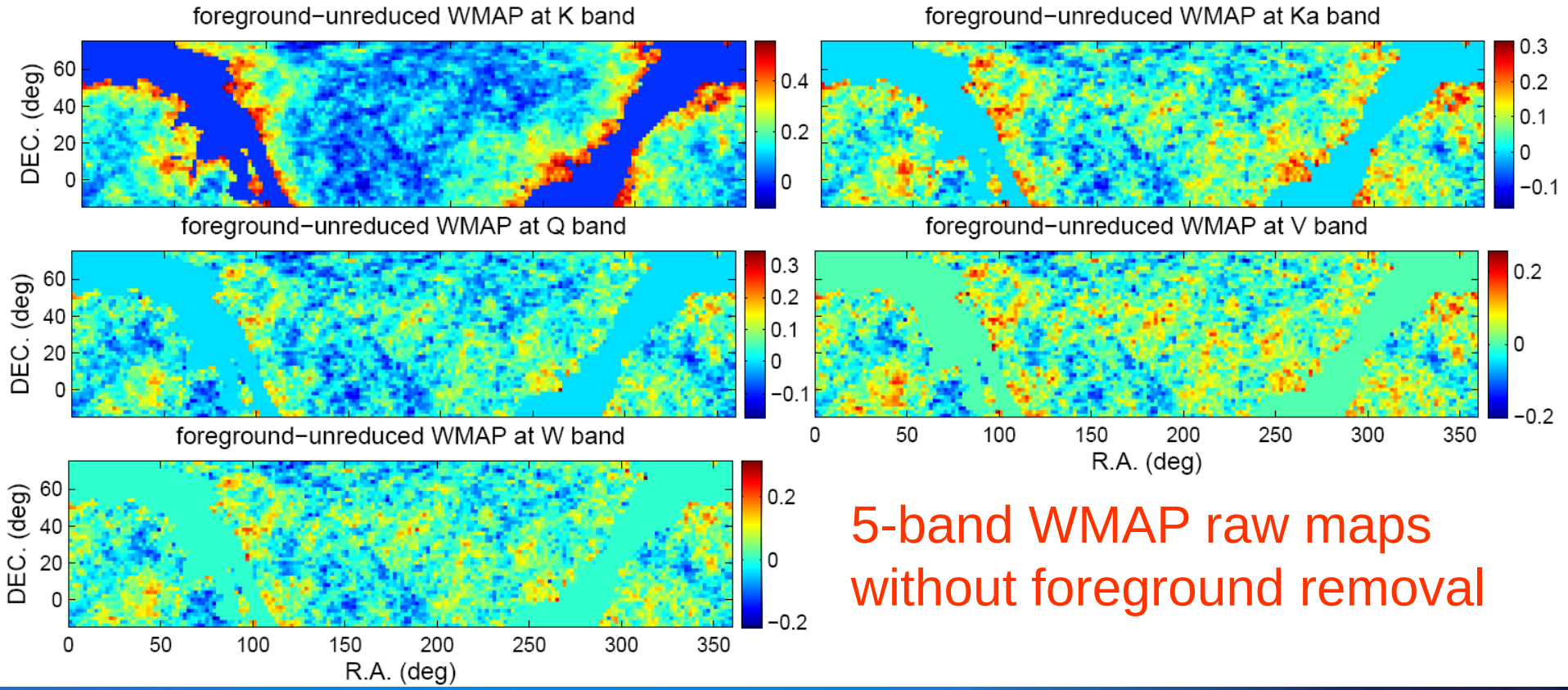
Cosmic rays sky maps



Amenomori et al 2006, Science

Data from Tibet YBJ China-Japan collaboration air-shower array for more than 10 years

WMAP maps in the same sky region as Tibet YBJ cosmic rays maps

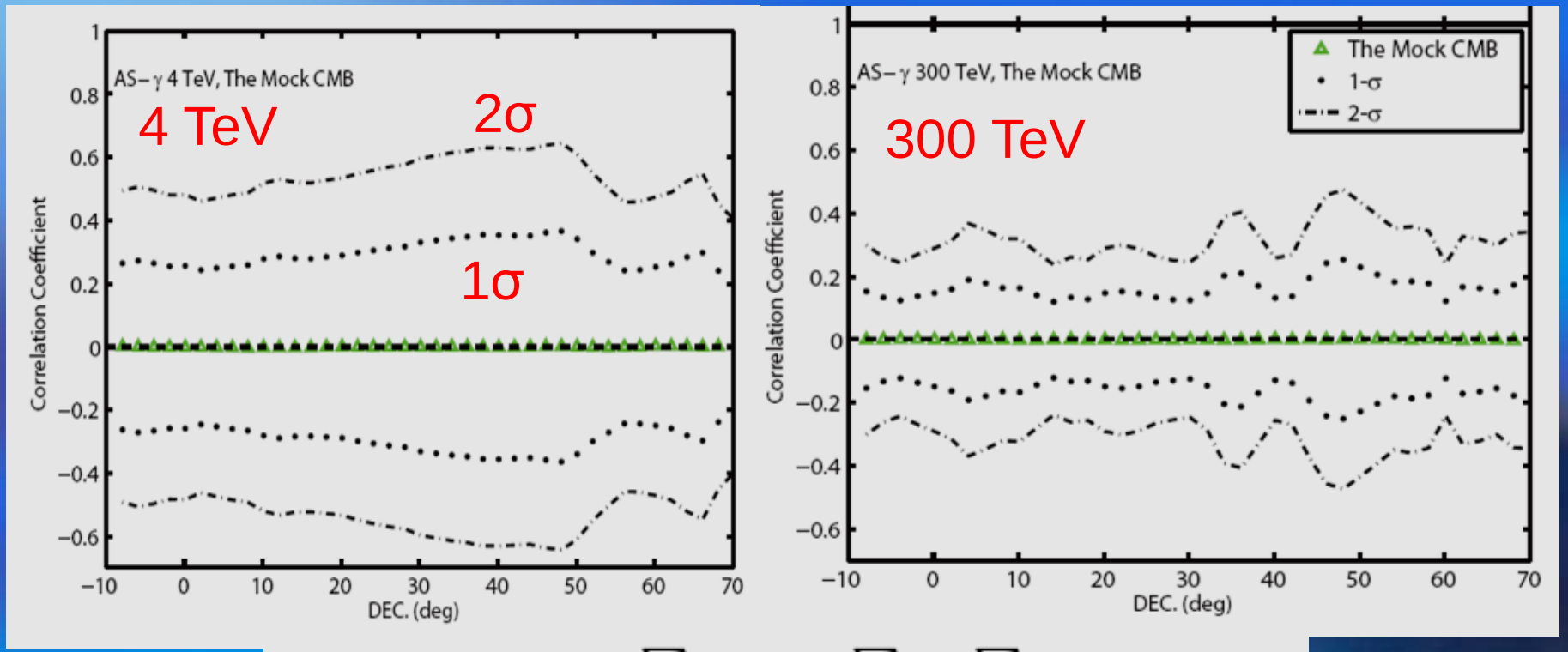


5-band WMAP raw maps without foreground removal

When doing correlation analysis between YBJ CR maps and WMAP CMB maps, the Galactic disk and other regions with strong radio sources are masked out (WMAP KP0 mask).

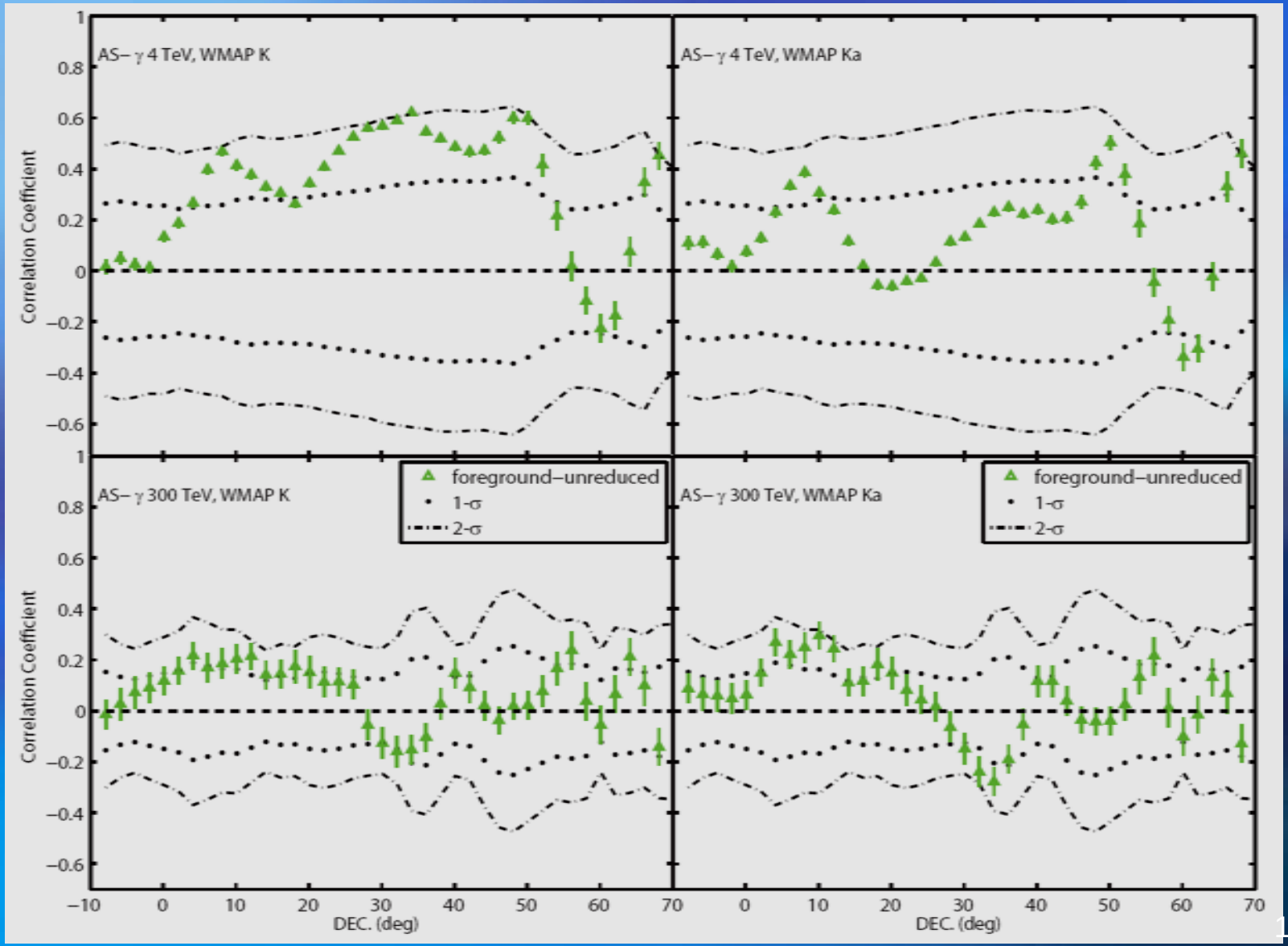
Correlation between CR & Mock CMB

1σ & 2σ bounds are obtained from correlation with 10^4 mock CMB maps: Cosmic variance

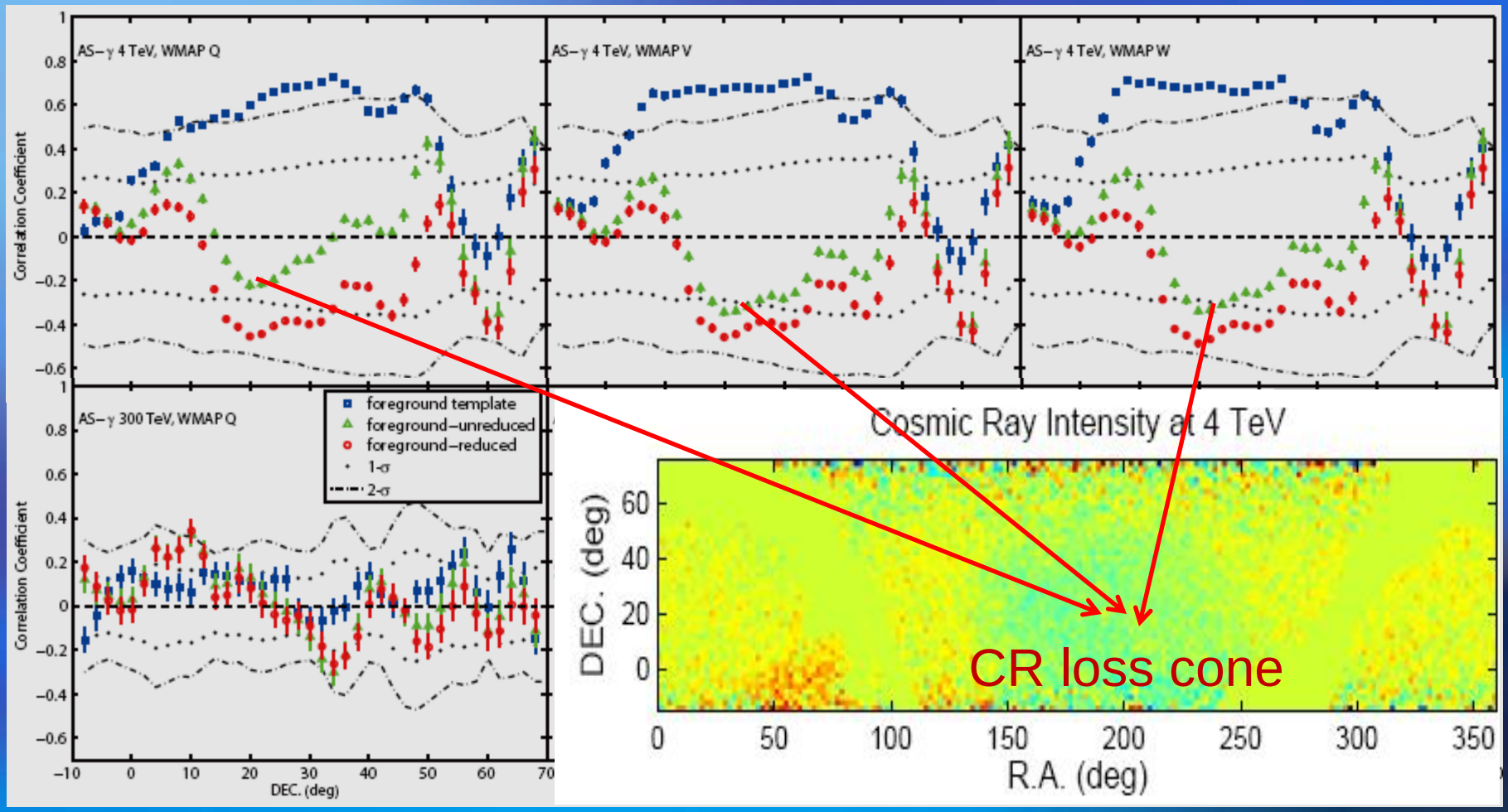


$$r_{xy}^{\mathrm{I}} = \frac{n\sum_i x_i y_i - \sum_i x_i \sum_i y_i}{\sqrt{n\sum_i x_i^2 - (\sum_i x_i)^2}\sqrt{n\sum_i y_i^2 - (\sum_i y_i)^2}},$$

WMAP Foreground & CR



“Cleaned” WMAP & CR



Enhanced “CMB” in loss cone: under-subtraction of foreground emission?

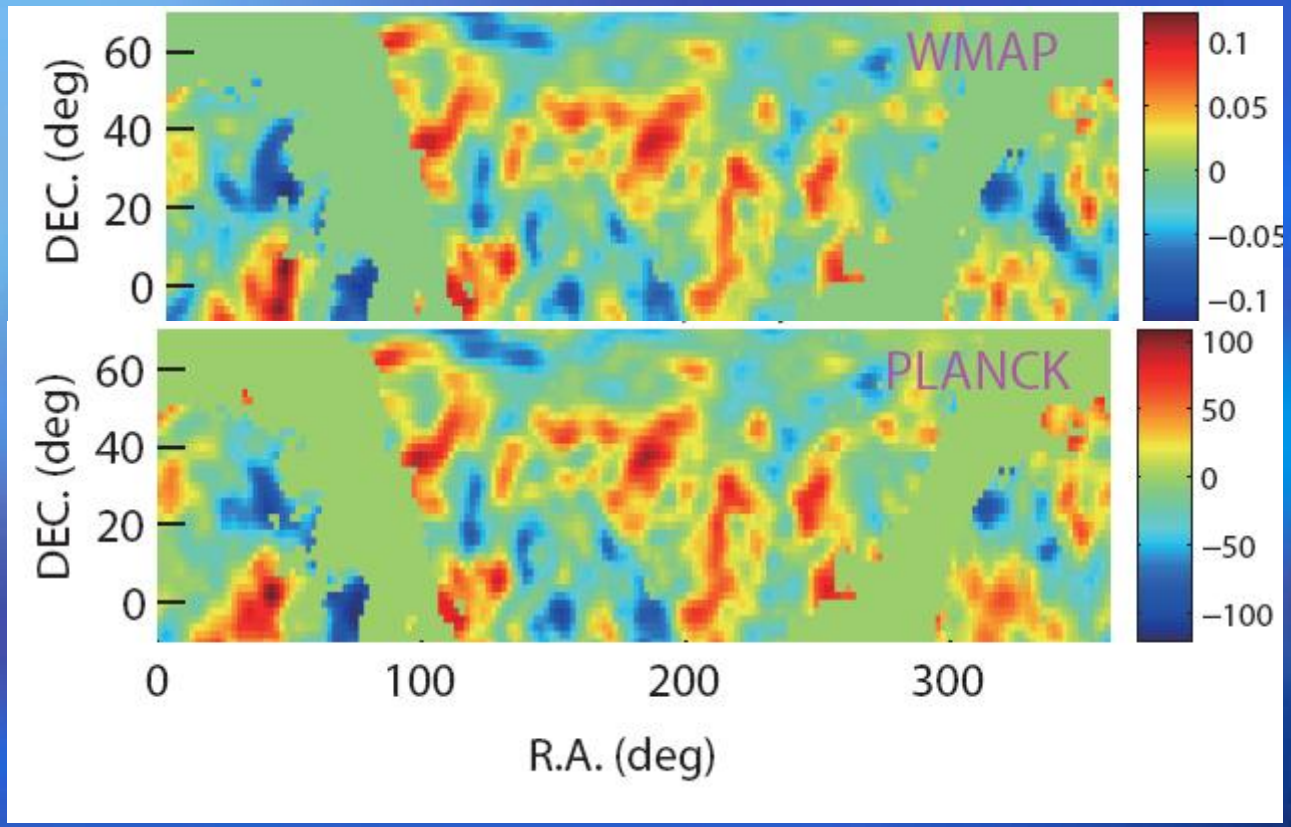
Significance of correlation: 85-95%

	Q band (%)	V band (%)	W band (%)	ILC (%)
4 TeV	$14.1^{+1.5}_{-1.3}$	$13.6^{+1.2}_{-1.4}$	$11.6^{+1.2}_{-1.4}$	$16.3^{+2.3}_{-2.0}$
6 TeV	$7.1^{+0.9}_{-0.8}$	$6.8^{+0.8}_{-0.9}$	5.6 ± 0.7	$9.2^{+1.7}_{-1.5}$
12 TeV	$5.2^{+0.9}_{-0.6}$	$5.0^{+0.7}_{-0.6}$	$4.1^{+0.6}_{-0.7}$	$7.4^{+2.0}_{-1.4}$

Cosmic variance is included and dominates large scale structures.

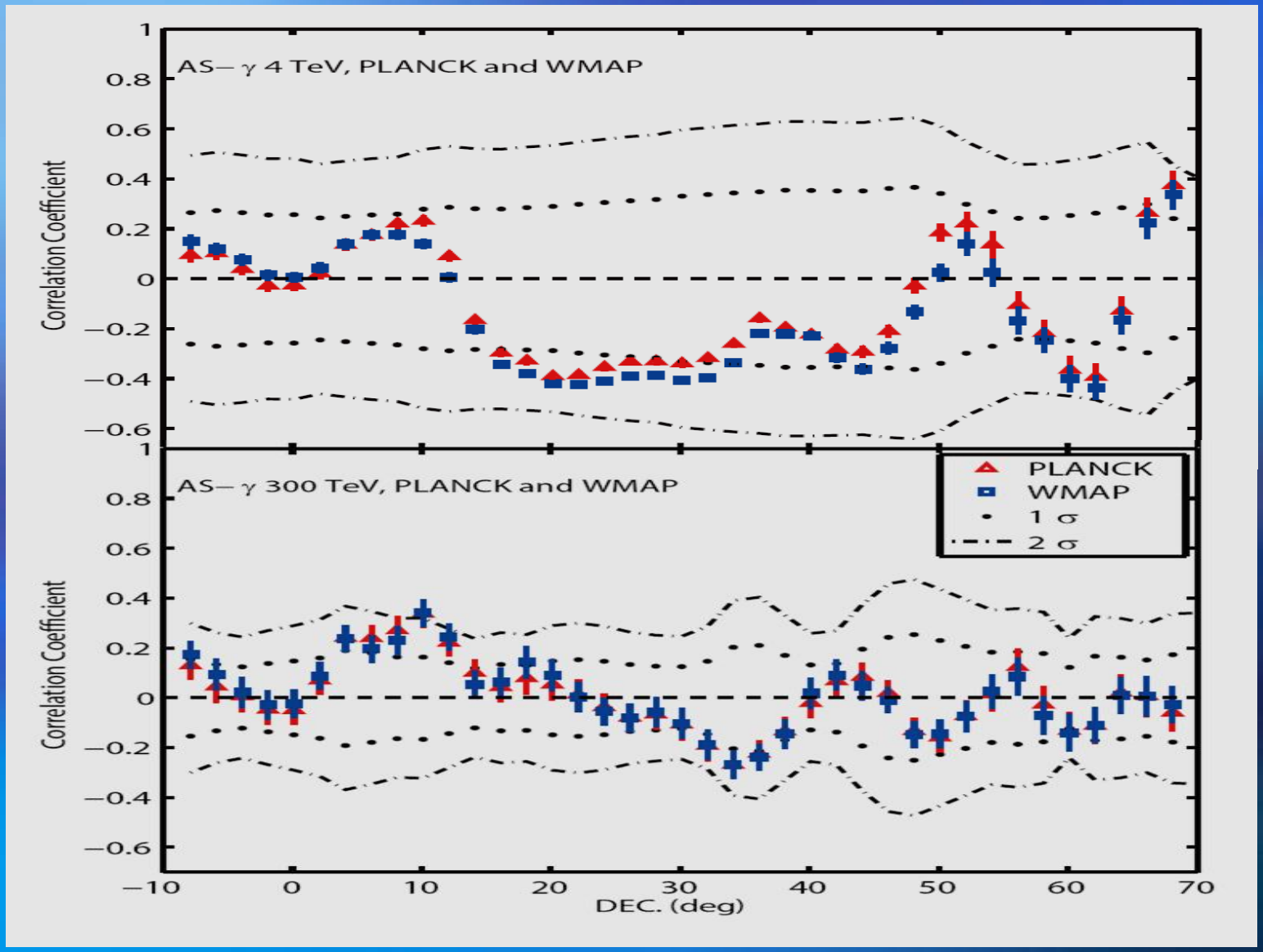
Yin, QQ, Zhang, SN, 2014, to be submitted

WMAP & Planck



Smoothed to the same 5 deg resolution: almost identical!

CR – WMAP/Planck: almost identical



Summary

- Wavelet analysis on non-gaussianity
  - Several cold and hot spots found.
- WMAP and γ-ray correlation
  - Blame CRs?
- New point source detection in WMAP data
- Unexplained non-blackbody fluctuations
- Cosmic ray – WMAP/Planck correlation
  - Under-subtraction of CMB foreground in loss cone
  - Cosmic variance of CMB map dominates large scale structure fluctuations of CMB

Many thanks for your attention!