Stacking and CMB Anomalies

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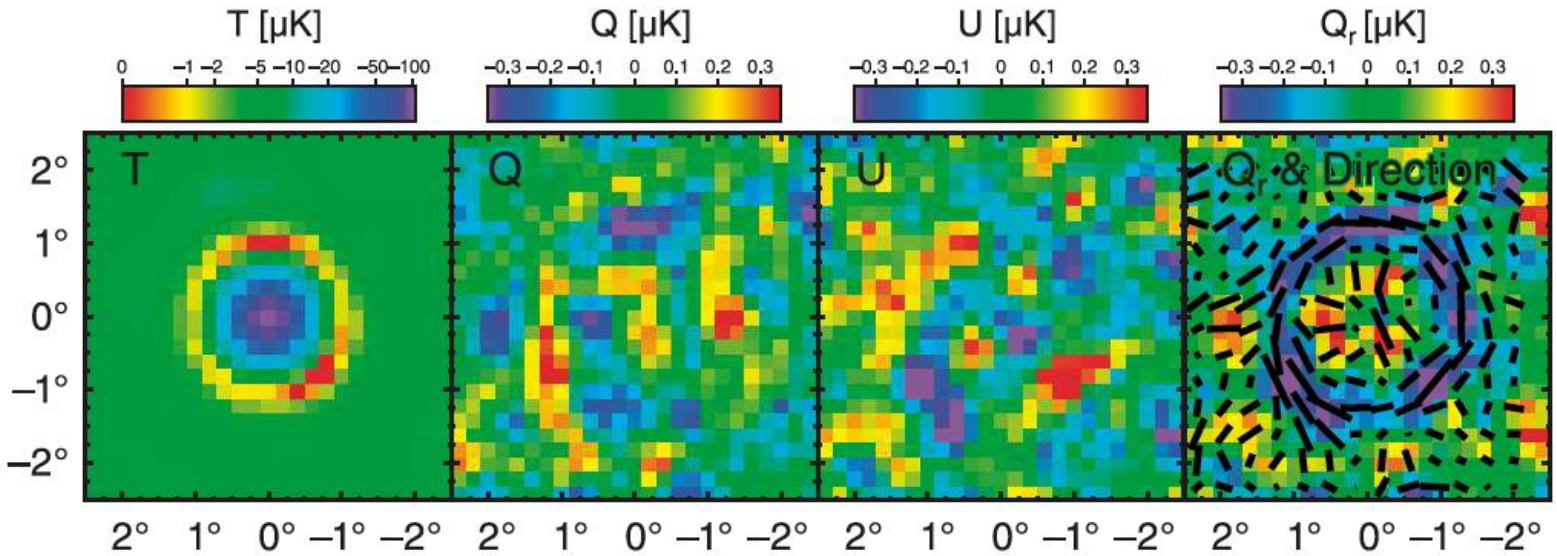
Outline

Back to WMAP era

WMAP7 Stacking:



Smooth maps $\Rightarrow$ Find T peaks $\Rightarrow$ cut out the $T/Q/U/Q_r$ patches around the T peaks and stack them

Why Stacking?

For statistically isotropic Gaussian fields, C_ℓ's contain all the information, why bother stacking?

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Why Stacking?

Stacking can be used to study

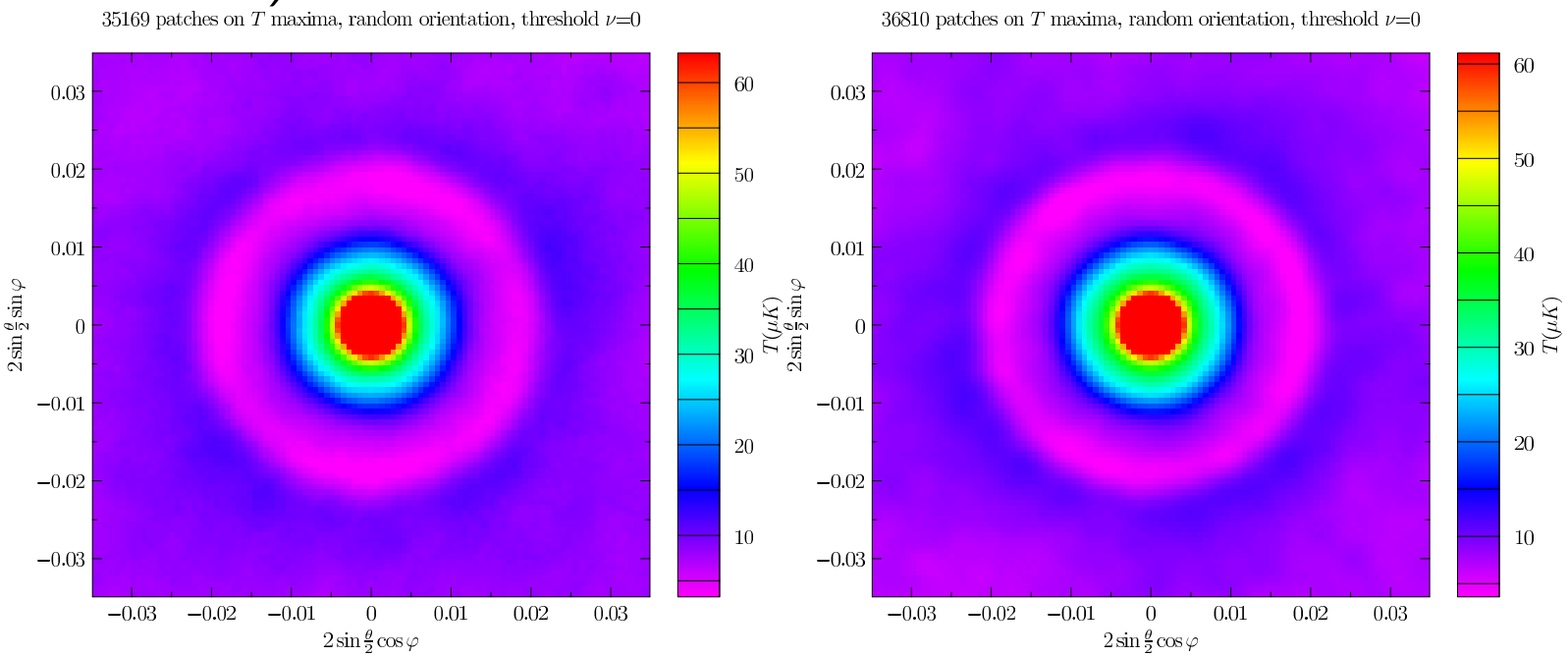
- NonGaussianity
- Anomalies

Compared to Fourier space analysis, stacking is

- local $\Rightarrow$ no mask effects.
- more intuitive $\Rightarrow$ find unknown systematics.

Planck Era

Planck 13 v.s. Noise-free simulation (T on T peaks, random orientation)



The Stacking Family

Three key elements:

A What to stack?

B Where to stack? (selection of patches)

C How to stack? (orientation of patches)

WMAP v.s. Bond, Frolov & Huang ($\in$ Planck core team)

	WMAP	BFH
What	T, Q, U, Q_r, U_r	T, Q, U, Q_r, U_r, E, B, Q_T, U_T, ζ, ...
Where	T peaks	T, E, Q^2+U^2, $Q_T^2+U_T^2$, ζ ... peaks
Orientation	random	random or oriented

How to orient a patch around a peak

First derivative vanishes on the peak. Need to use the 2nd derivatives:

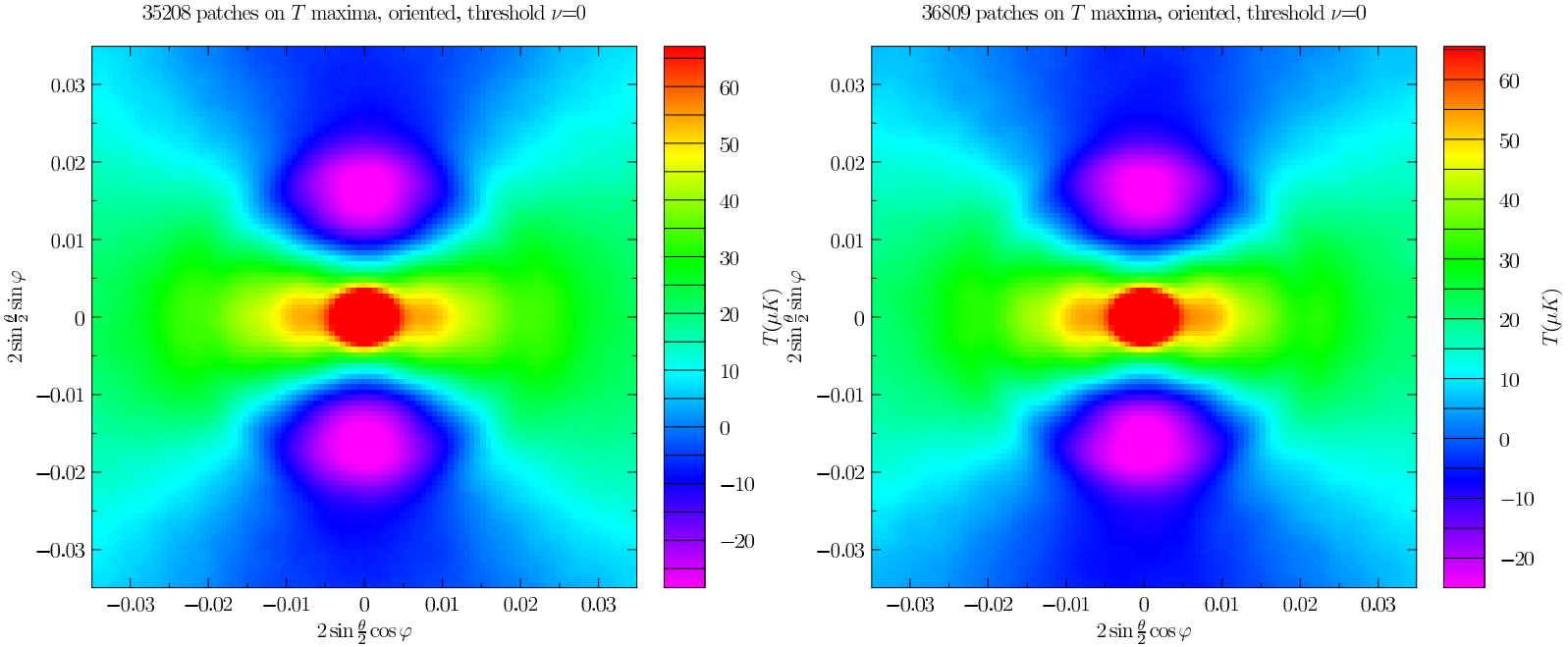
Intuitively (flat-sky limit):
$Q_T \equiv \frac{1}{2}\nabla^{-2}(\partial_x^2 - \partial_y^2)T$, $U_T \equiv \nabla^{-2}(\partial_x\partial_y)T$

Slightly non-intuitive (on the sphere):
$Q_T(\mathbf{n}) \pm iU_T(\mathbf{n}) \equiv \sum_{l,m}\left[\int T(\mathbf{n}')\, Y^*_{lm}(\mathbf{n}')\, d^2\mathbf{n}'\right]\, {}_{\pm 2}Y_{lm}(\mathbf{n})$

Orientation of the spin-2 field:
$\varphi = 1/2\times$ the pahse of $(Q_T + iU_T)$.

Oriented Stacking

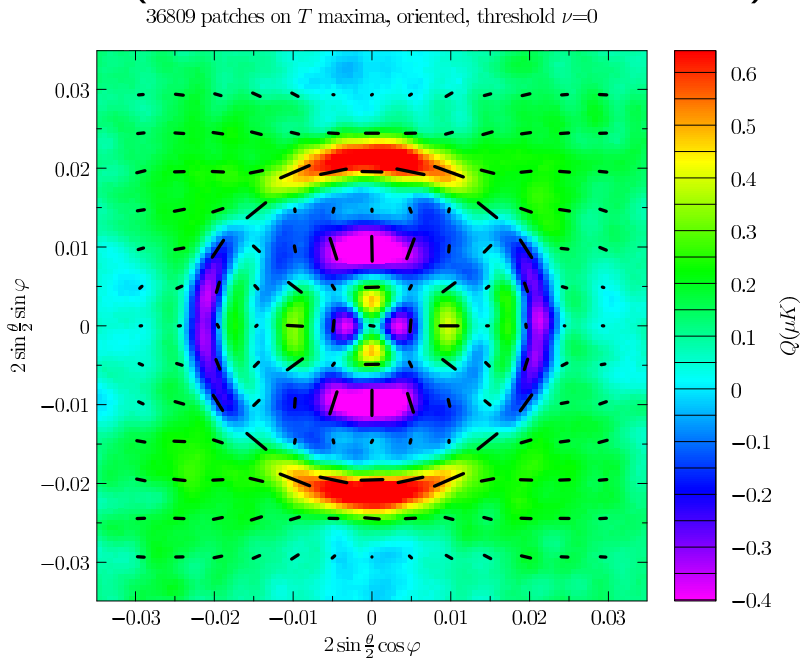
Planck 13 v.s. noise-free simulation (T on $T_{\max}$, oriented)



Angular dependence ($\cos m\phi$, m = 0, 2)

Oriented Stacking

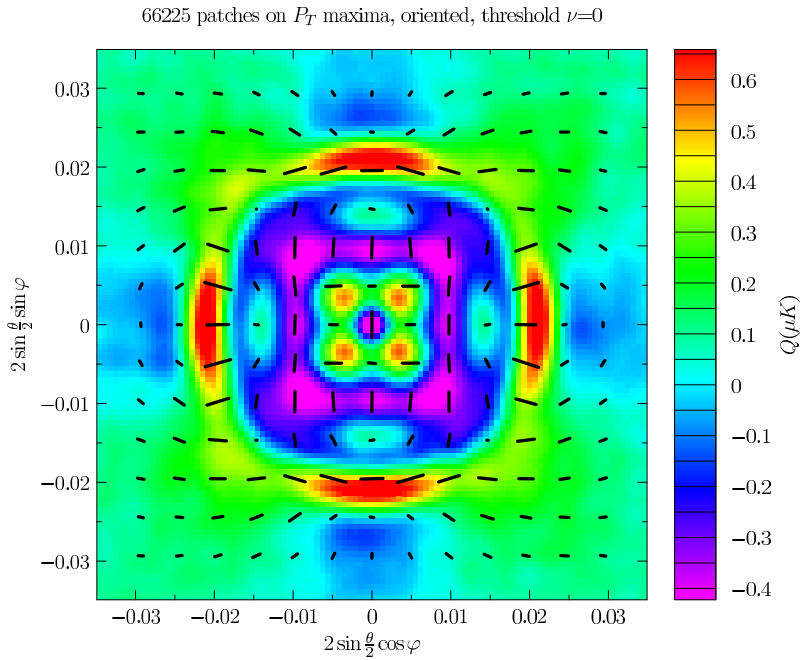
Planck 14 v.s. noise-free simulation (Q on T peaks, oriented)



Angular dependence ($\cos m\phi$, m $= 0, 2, 4$)

Oriented stacking

Planck 14 v.s. noise-free simulation (Q on $Q_T^2 + U_T^2$ peaks, oriented)



Angular dependence ($\cos m\phi$, m $= 0, 4$)

CMB Anomalies

Planck 13/WMAP:

- Hemispherical Asymmetry
- Cold Spot
- Quadrupole-Octople alignment
- Power deficit at low ℓ's

Cosmological or unknown systematics?

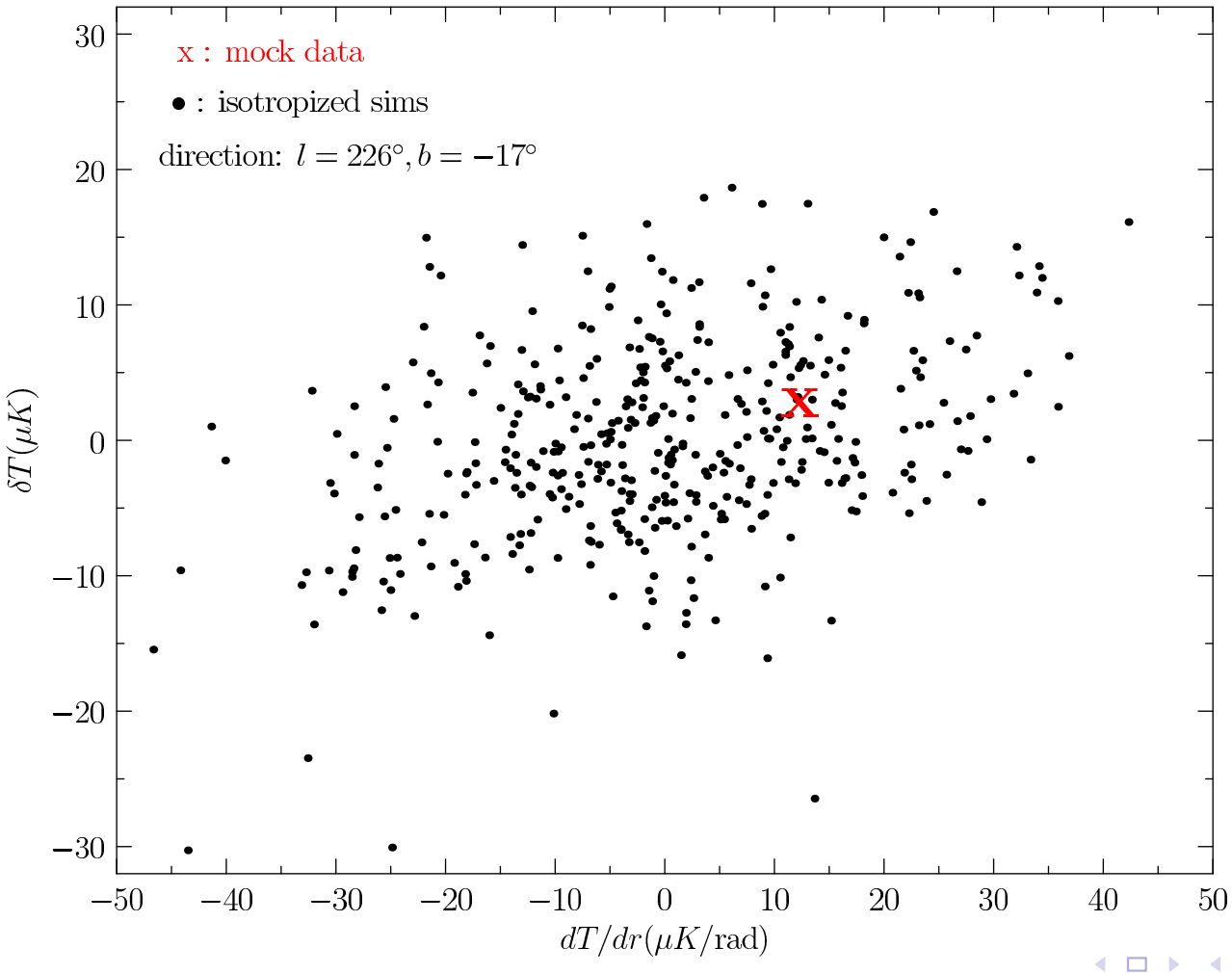
Using stacking to study hemisphere asymmetry

Recipe: map + axis $\Rightarrow \delta T$, dT/dr

- Choose an axis to define "north hemisphere" and "south hemisphere".
- Stack T on T peaks for two hemispheres, respectively.
- Approximate the difference of the radial profiles of stacked maps with a linear function $T_{\rm north}(r) - T_{\rm south}(r) = \delta T + \frac{dT}{dr} r$. (average over angular dependence + least square fit on r)

Using stacking to study hemisphere asymmetry

black dots are simulations, red x is data



Conclusion and Prospects

- We have proposed a large class of new stacking methods.
- These methods can be used to study CMB anomalies from a different aspect (more intuitive, no mask effects, ...).
- These method can be applied to non-Gassian maps (applied on Planck dust maps).
- Can also be interesting on very small scales (working on ACTPol maps).