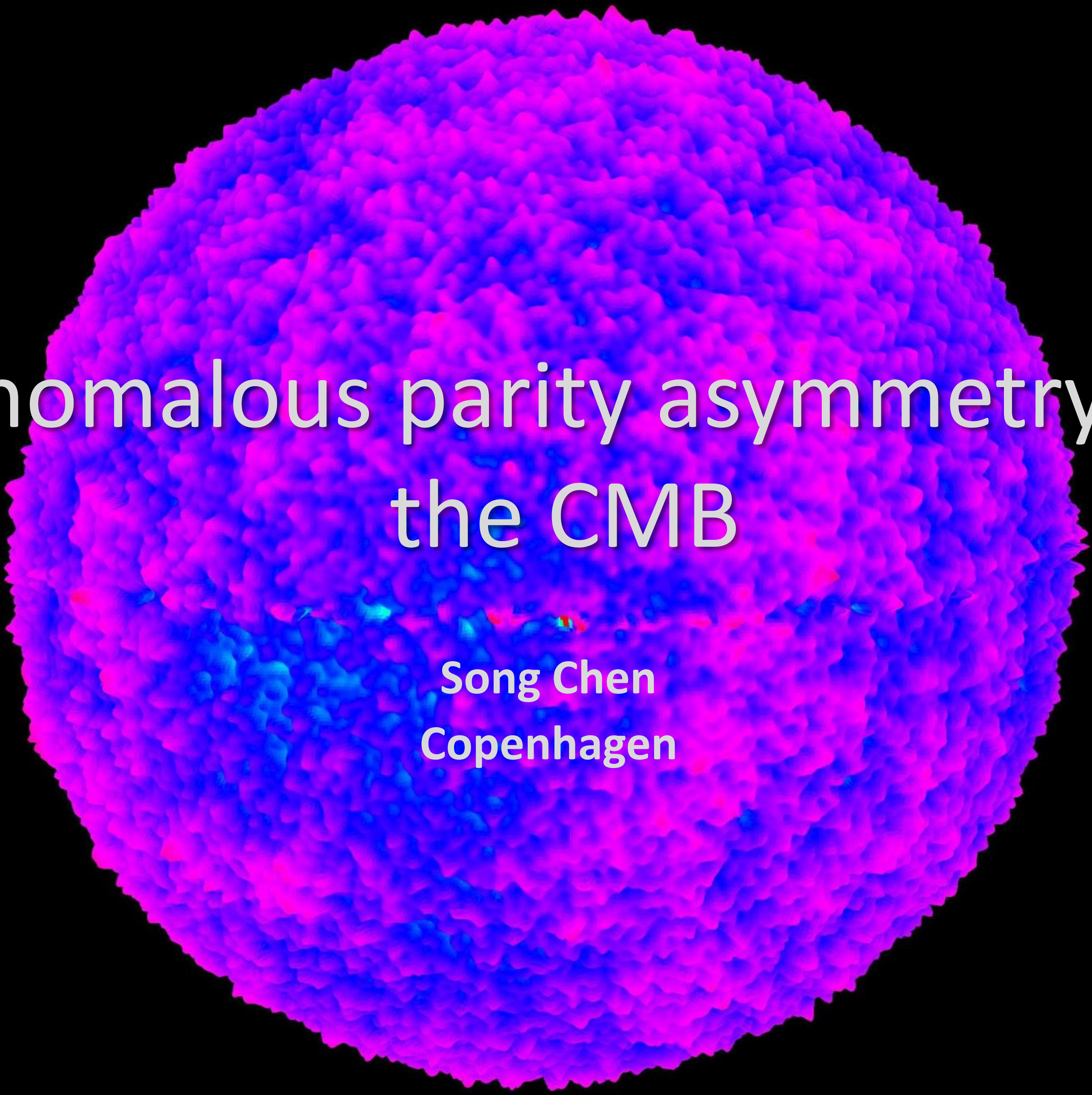


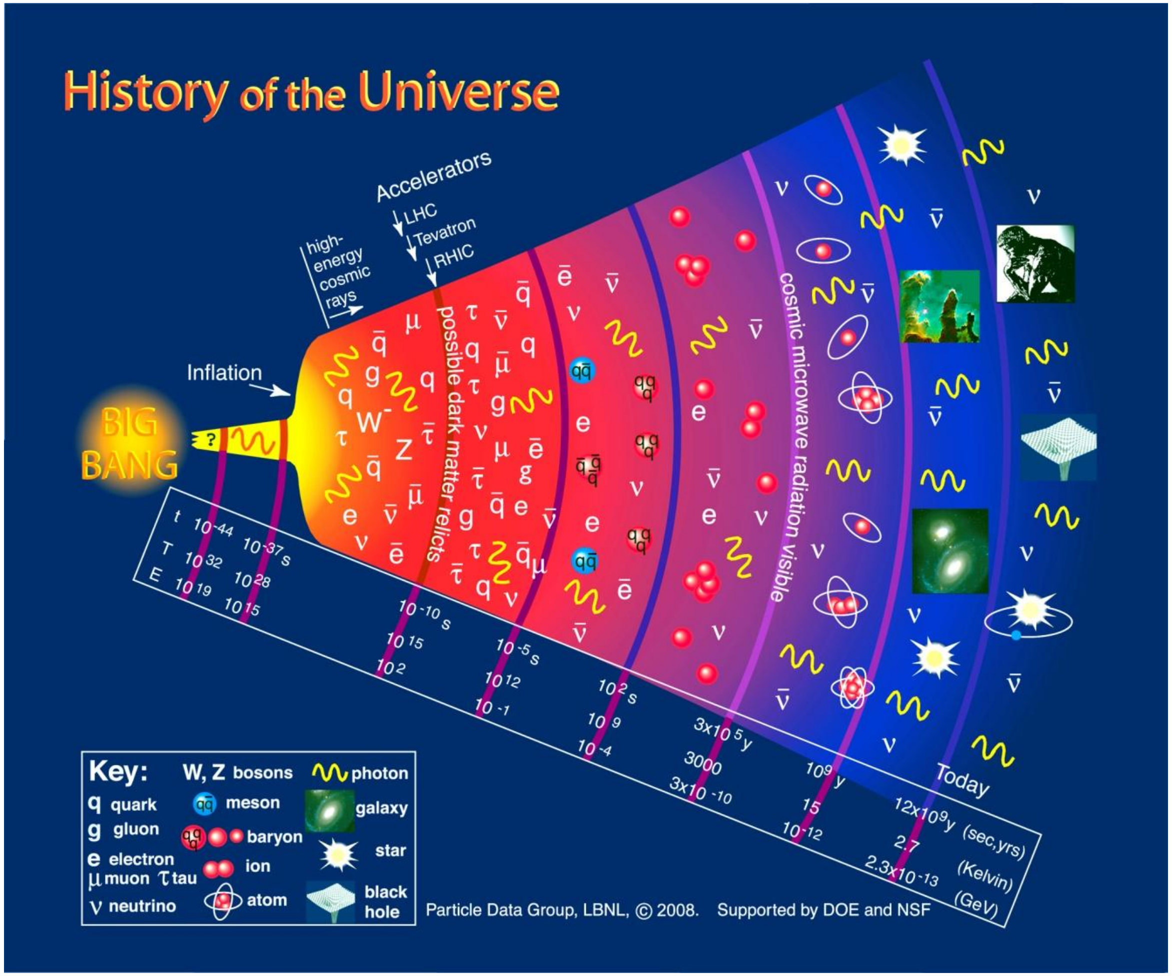
Anomalous parity asymmetry of the CMB

Song Chen
Copenhagen

My talk is based on this paper:

arXiv: 1108.4376v3 astro-ph

Background



History of the Universe
Accelerators
LHC
Tevatron
RHIC
high-energy cosmic rays
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
Today
Key:
q quark
g gluon
e electron
μ muon τ tau
ν neutrino
W, Z bosons
meson
baryon
ion
atom
photon
galaxy
star
black hole
Particle Data Group, LBNL, © 2008. Supported by DOE and NSF

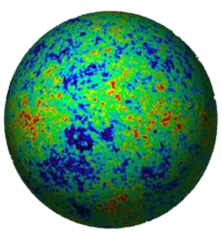
General definitions

In the real space, a sky map of CMB fluctuation can be characterized in term of the correlation function :

$$< \Delta T\ (\hat{q}_1)\ \Delta T\ (\hat{q}_2)) > = \ C(\theta) = \frac{1}{4\pi} \sum_l^{\infty} (2l+1) C_l W_l P_l(\cos\theta)$$

In harmonic space, we have the similar two-point function called angular power spectrum C_ℓ :

$$< a_{lm} a_{l'm'} >= \delta_{l,l'} \delta_{m,m'} C_l \ .$$



Temperature maps are decomposed into spherical harmonics :

$$\Delta T(\theta, \phi) \ = \sum_{l=1}^{\infty} \sum_{m=-l}^{l} a_{lm} Y_{l,m}(\theta, \phi) \ .$$

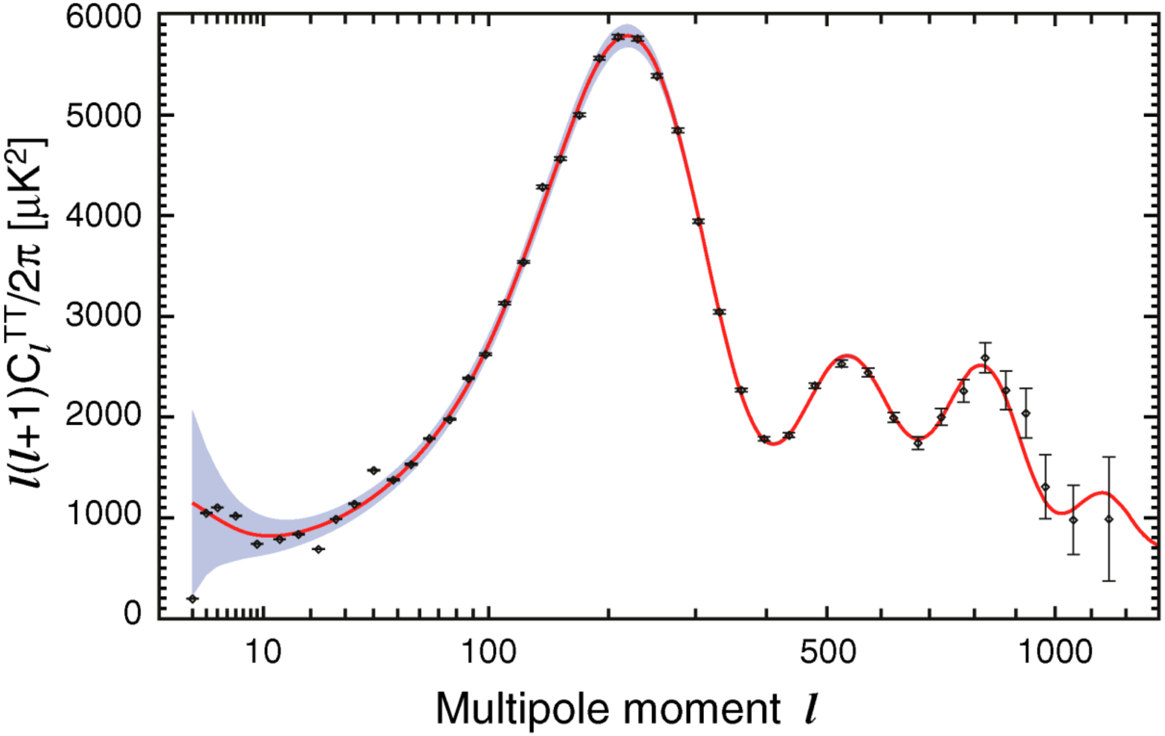
The angular power spectrum can be estimate as:

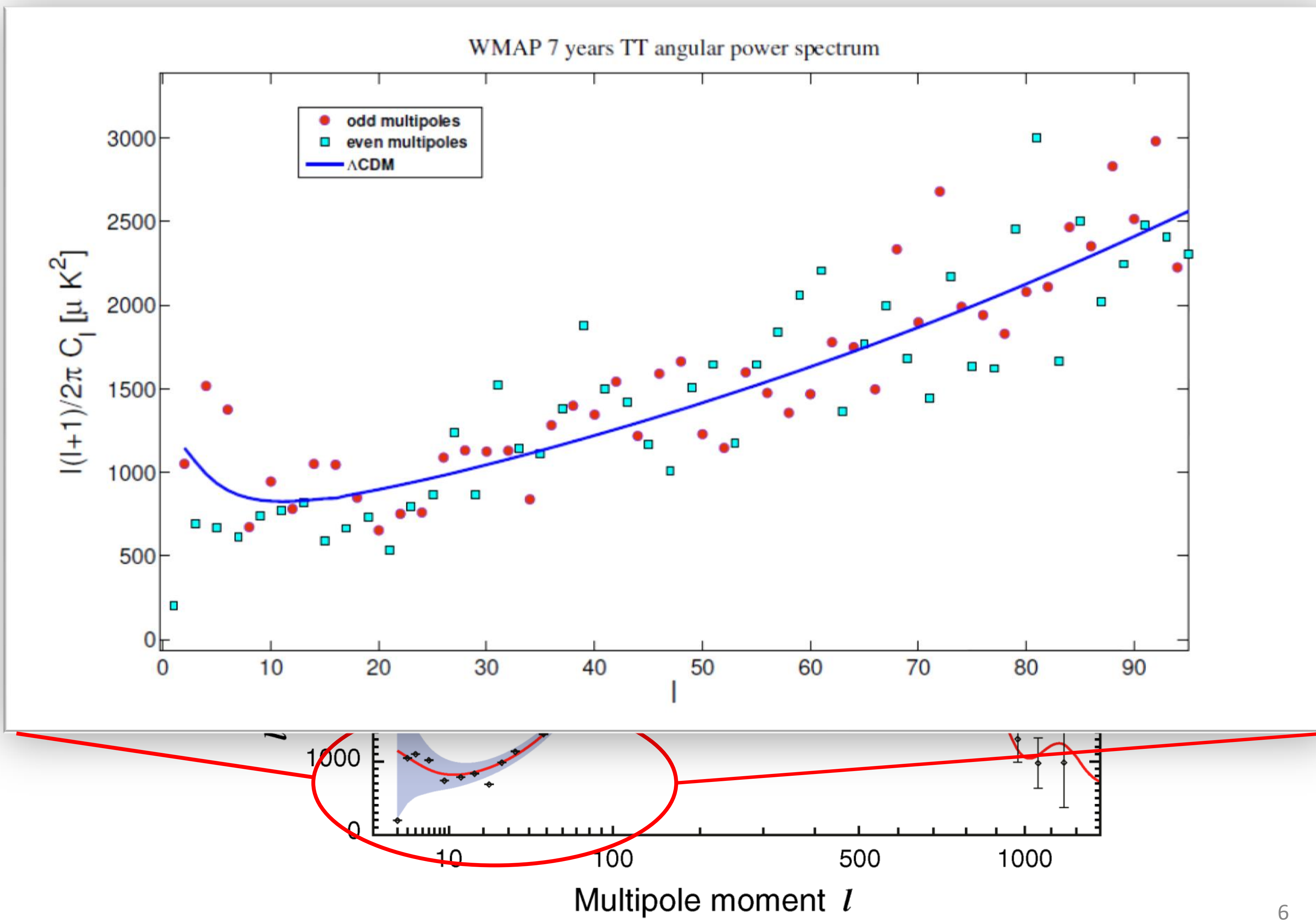
$$\widehat{C}_\ell \equiv \frac{1}{2\ell + 1} \sum_{m=-\ell}^{\ell} |a_{\ell m}|^2 \ .$$

Low-ℓ anomalies

In multipole space

1. lacking power of quadrupole
2. Even number multipoles lower than the odd

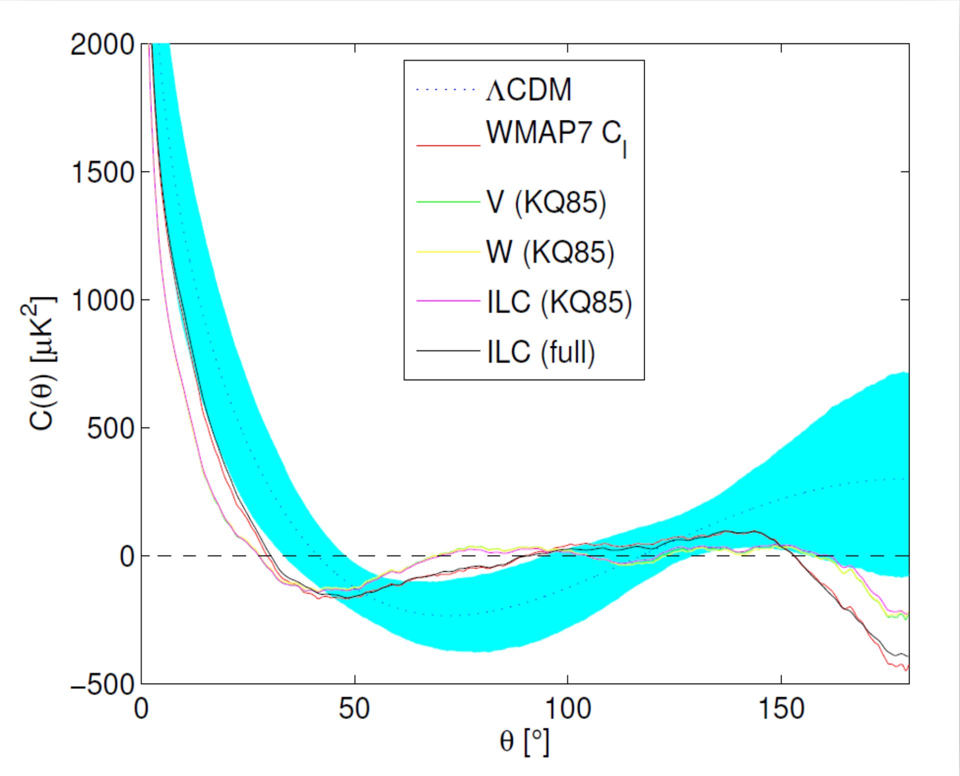



WMAP 7 years TT angular power spectrum
odd multipoles
even multipoles
ΛCDM
$l(l+1)/2\pi C_l$ [μ K^2]
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
90
l
1000
0
10
100
500
1000
Multipole moment l

Low-ℓ anomalies

In the real space

Two point angular correlation function

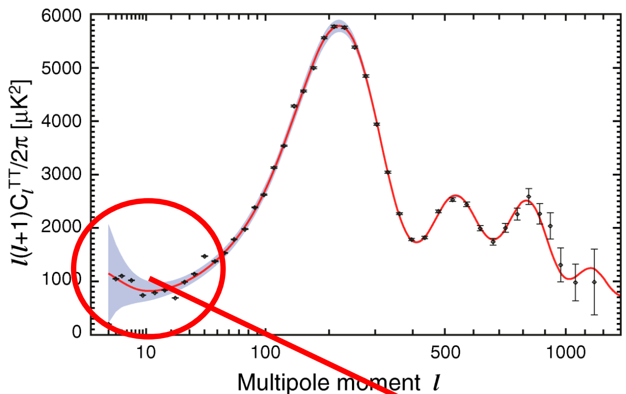


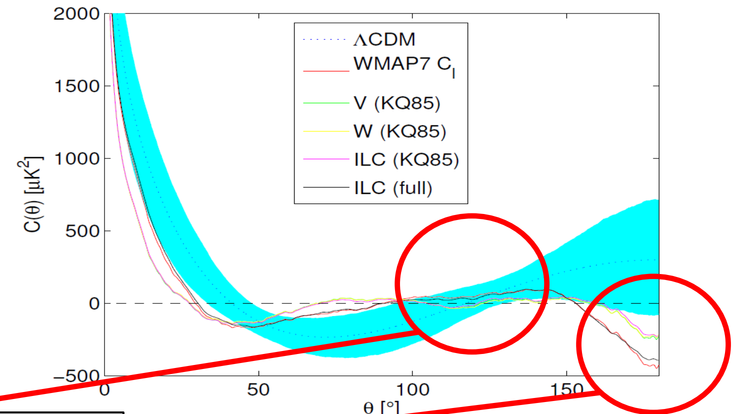
1. Near vanishing of two-point angular correlation function C(Θ) at angular 60 ° ~120 °
2. Significant negative correlation for C(180 °)

Low-ℓ anomalies

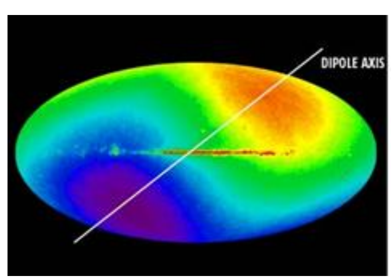
arXiv:1011.0377v6 shows:

“Those low-ℓ anomalies are not independent”





“Parity asymmetry”



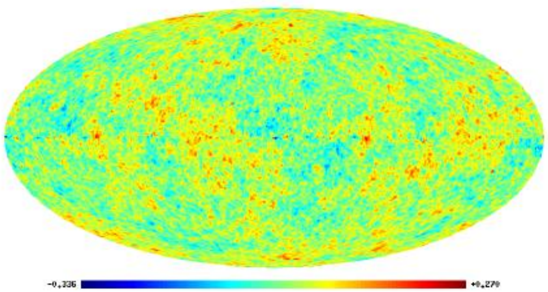
?

Map Decomposition

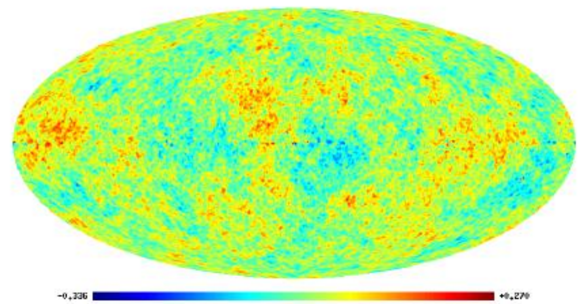
Any $T(\hat{\mathbf{n}})$ defined on the sphere, can be decomposed into symmetric component $T^{+}(\hat{\mathbf{n}})$ and anti-symmetric component $T^{-}(\hat{\mathbf{n}})$

$$\Delta T^{\pm}(\hat{\mathbf{n}}) = \sum_{l} \sum_{m=-l}^{l} a_{lm} \Gamma^{\pm}(l) Y_{lm}(\hat{\mathbf{n}})$$

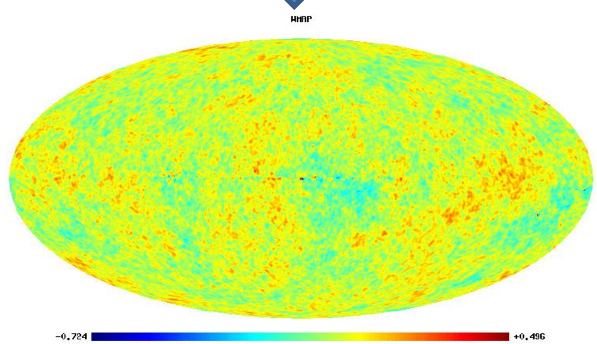
$$\Gamma^{+}(l) \equiv \cos^2(\tfrac{\pi l}{2}),\ \Gamma^{-}(l) \equiv \sin^2(\tfrac{\pi l}{2}),\ Y_{lm}(\hat{\mathbf{n}}) = (-1)^l\, Y_{lm}(-\hat{\mathbf{n}})$$



(a) Even parity map $T^{+}(\hat{n})$



(b) Odd parity map $T^{-}(\hat{n})$



Parity function

The parity preference can be characterized by the following parameter

$$C_{th}(\Theta = \pi) = \sum_{l=l_{\min}}^{\infty} \frac{2l+1}{4\pi} C_{th}(l)(\Gamma^+(l) - \Gamma^-(l))$$

We define a function which shows the relative contribution of even and odd multipoles to the correlation function :

$$g(l) = \frac{\sum_{l'=l'_{\min}}^{l} \frac{2l'+1}{4\pi} C(l')\Gamma^+(l')}{\sum_{l'=l'_{\min}}^{l} \frac{2l'+1}{4\pi} C(l')\Gamma^-(l')}$$

If g=1 then there is no parity preference.
If g>1 then there is even parity preference.
If g<1 then there is odd parity preference.

Directional statistic

Rotation variant power spectrum D(ℓ)

$$D(l) \equiv \frac{1}{2l+1} \sum_{m=-l}^{l} |a_{lm}|^2 (1 - \delta_{m0})$$

The rotated mode can be calculate in the following way

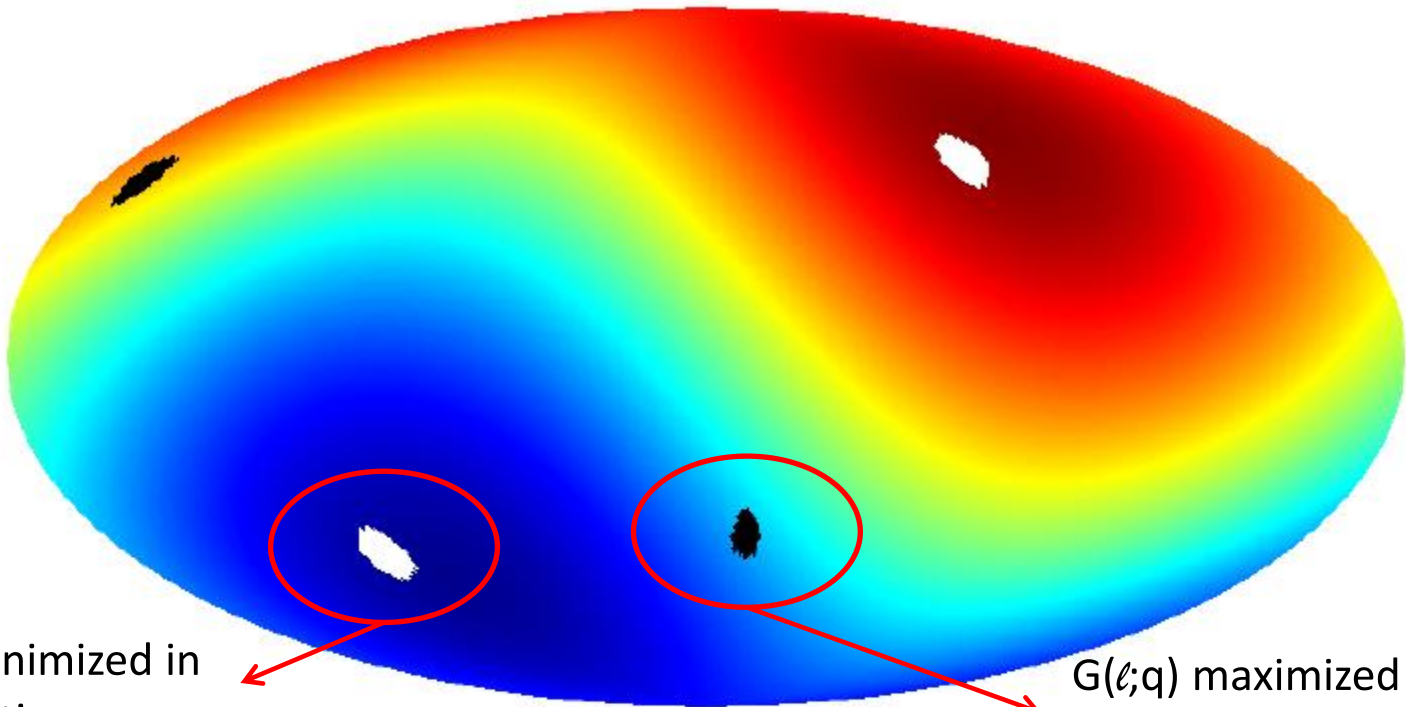
$$a_{lm}(\psi, \theta, \phi) = \sum_{m'=-l}^{l} a_{lm'} D^{l}_{mm'}(\psi, \theta, \phi)$$

Rotation variant parity parameter :

$$G(l; \hat{q}) = \frac{\sum^{\ell} \frac{2l'+1}{4\pi} C(l') \Gamma^{+}(l') - \sum^{\ell} \frac{1}{4\pi} a^{2}_{l0}(\hat{q}) \Gamma^{+}(l')}{\sum \frac{2l'+1}{4\pi} C(l) \Gamma^{-}(l') - \sum \frac{1}{4\pi} a^{2}_{l0}(\hat{q}) \Gamma^{-}(l')}$$

where $a^2_{l0}(\hat{\mathrm{q}}) \;=\; \sum_{mm'} a_{lm} a^{*}_{lm'} D^{l}_{0m}(\hat{\mathrm{q}}) D^{l\,*}_{0m'}(\hat{\mathrm{q}})$

The preferred direction



G(ℓ;q) minimized in this direction (46.59° , 277.98 °)

G(ℓ;q) maximized in this direction (50.55 ° , 167.34 °)

The direction of dipole is (48.26 ° 263.99 °) according to WMAP 7 years data

Discussion

- We do the cross-check for this result by using another rotation variant power spectrum

$$\tilde{D}(l) \equiv \frac{1}{2l+1} \sum_{m=-l}^{l} m^2 |a_{lm}|^2$$

We found the similar result.

- **CMB parity asymmetry and its related anomalies may relate to the contamination of the 'kinematic dipole' component.**