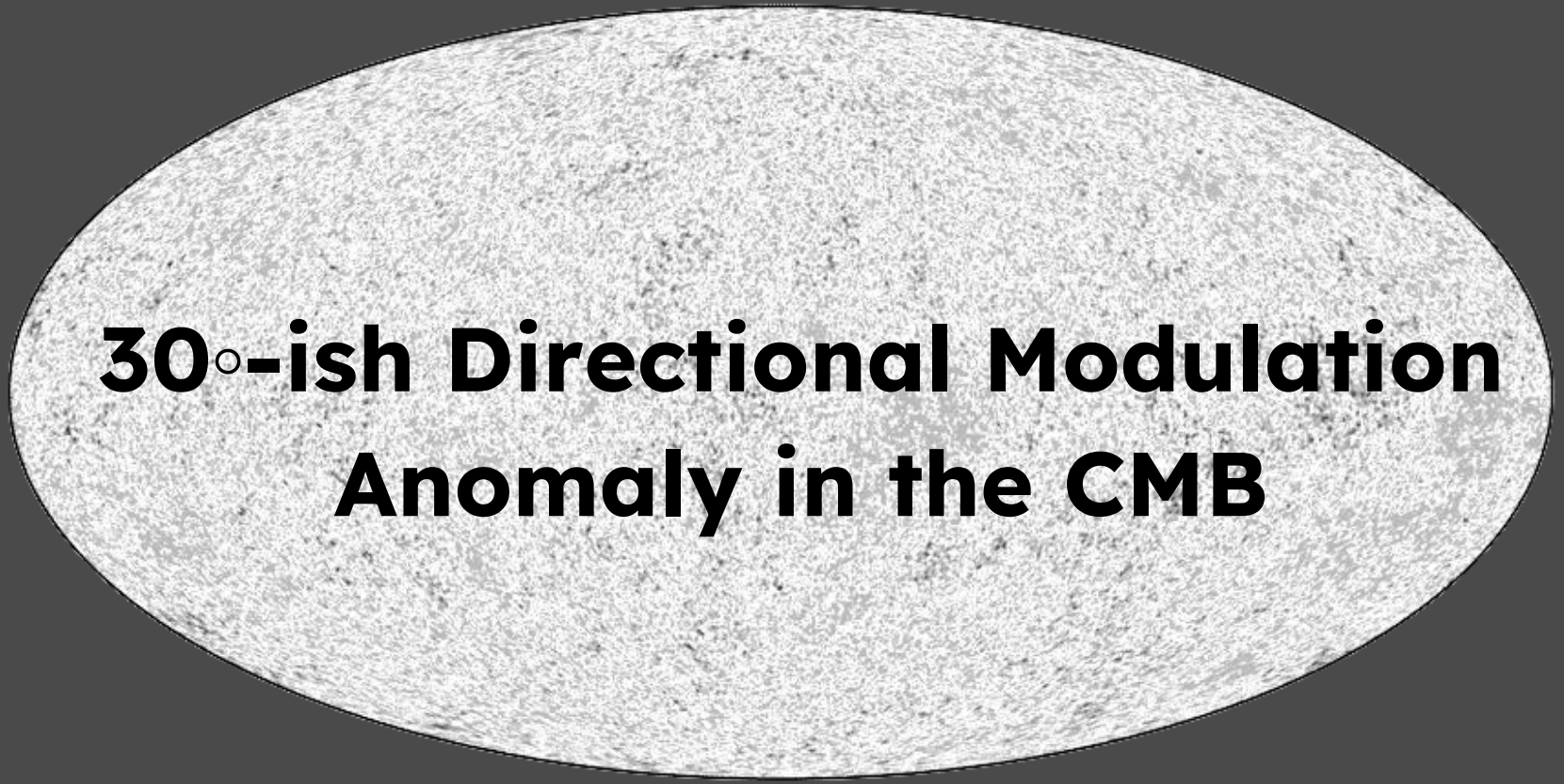


30◦-ish Directional Modulation Anomaly in the CMB

MohammadHossein Jamshidi - Abdolali Banihashemi - Nima Khosravi

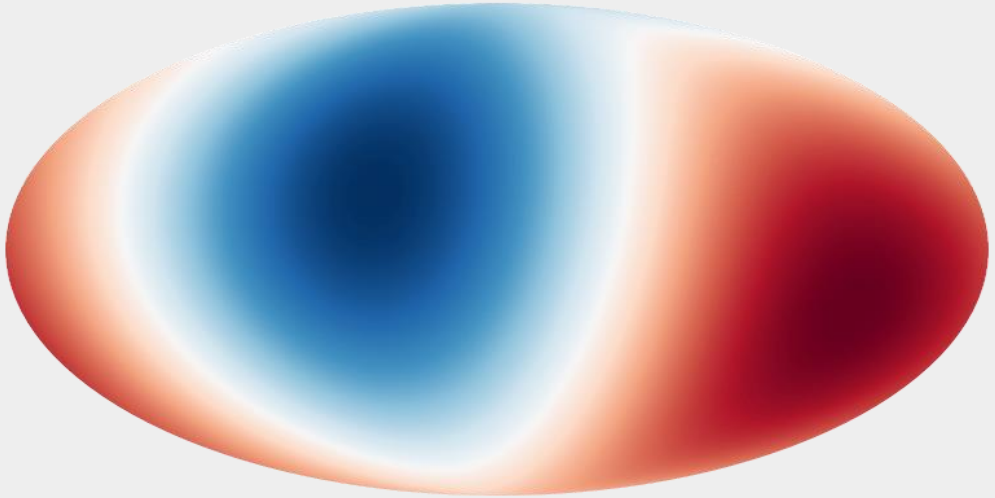
DSU2023 – Kigali

Statistical Assumptions in ΛCDM

- Homogeneity
- Isotropy

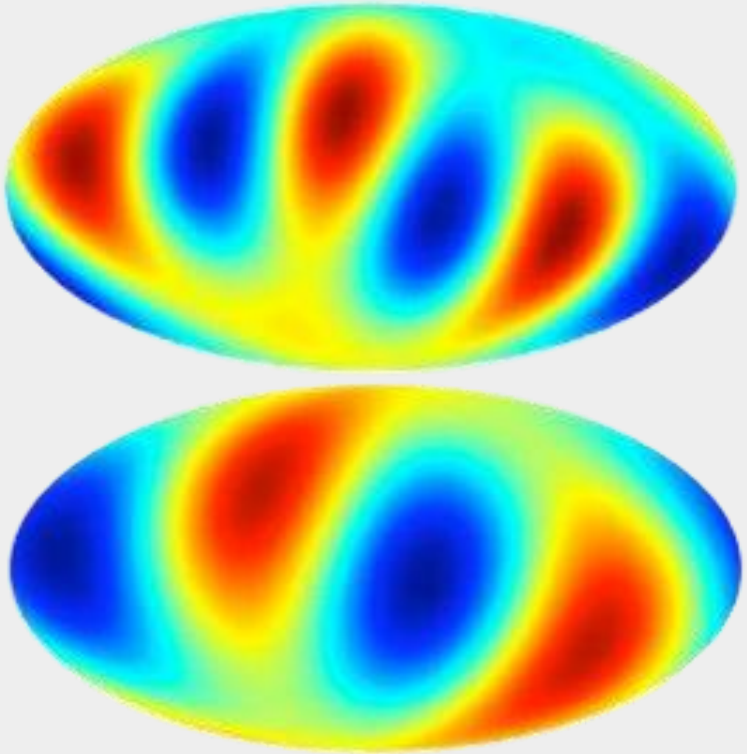
Known anomalies in the CMB

- Temperature Dipole
- Dipole in T fluctuations



Known anomalies in the CMB

- Temperature Dipole
- Dipole in T fluctuations
- Quadrupole-Octopole Alignment

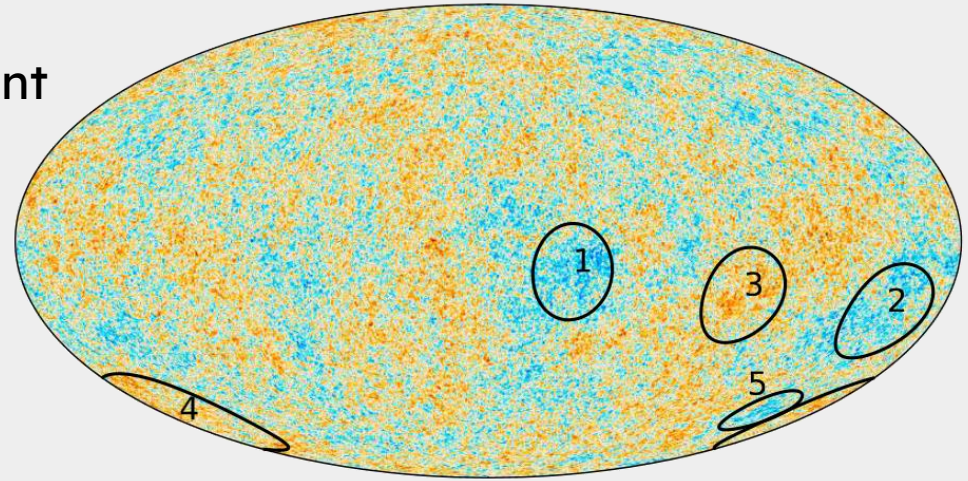


Planck VII 2018

https://doi.org/10.1155/2010/847541

Known anomalies in the CMB

- Temperature Dipole
- Dipole in T fluctuations
- Quadrupole-Octopole Alignment
- Cold Spots
- . . .



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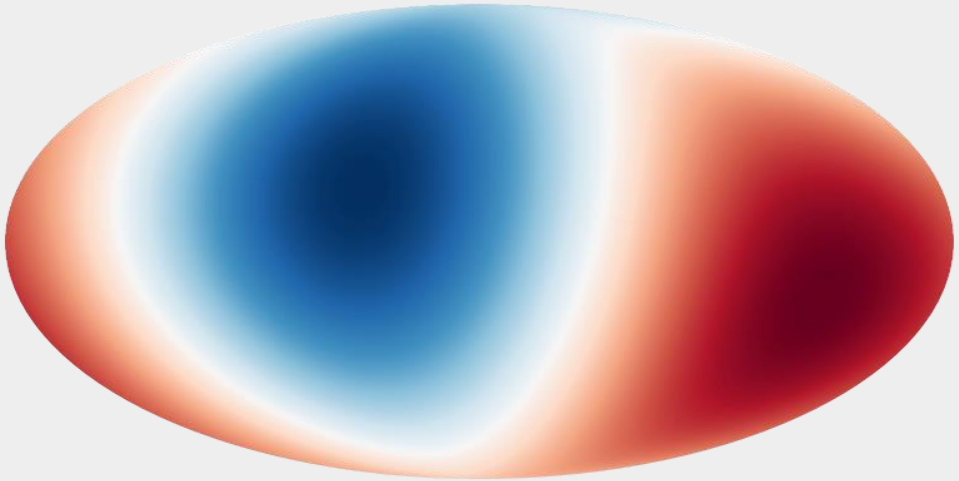
CMB dipole modulation

$$\frac{\Delta T}{T}|_{mod}(\hat{n}) = (1 + A\hat{n}.\hat{p})\frac{\Delta T}{T}|_{iso}(\hat{n})$$



Commander Dipole Amplitude:

$0.070\ ^{+0.032}_{-0.015}$

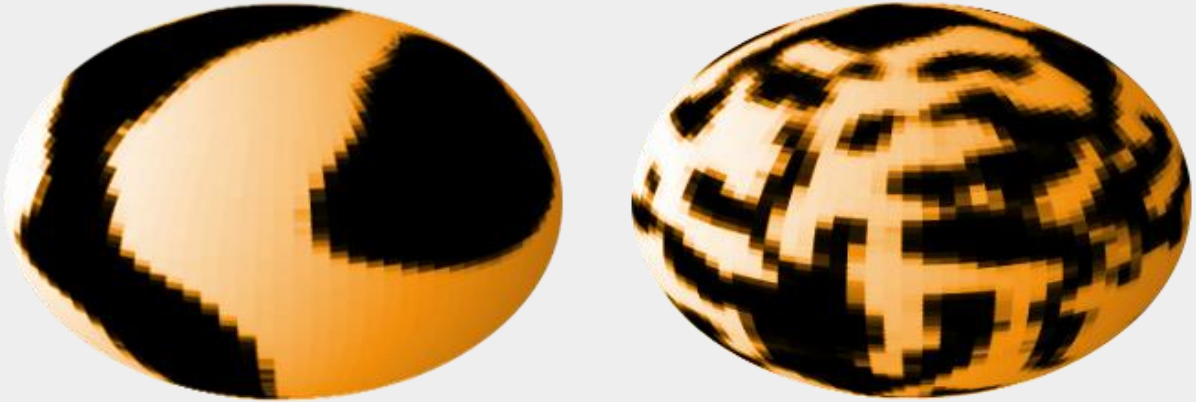
Planck VII 2018

Dipolar structure …?

- Custom function, Higher Multipoles ?
- Fine tuning in our location …
- …

Why did we think about it?

- GLTofDE Model
- Patches in the sky

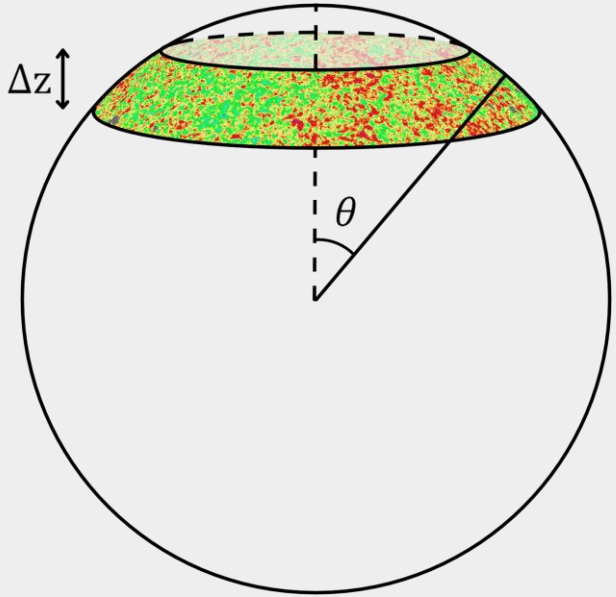


A.Banihashemi et. al 2018

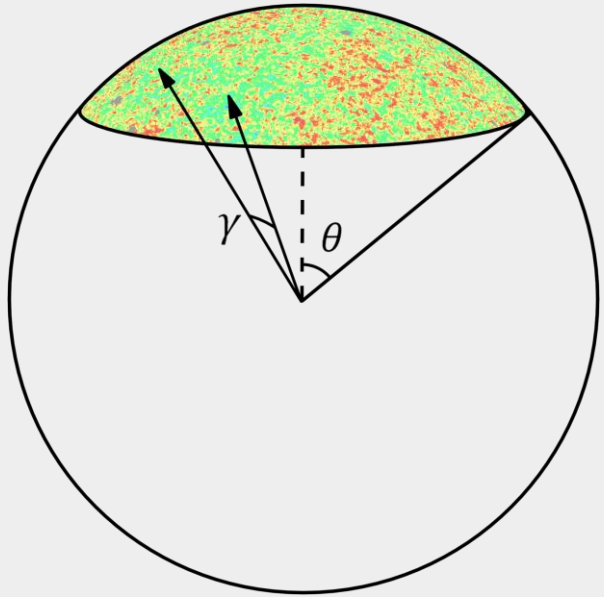
https://doi.org/10.1103/PhysRevD.99.083509

Does this anomaly have a finer structure?

Shapes



Strip



Cap

- Standard Deviation $\sigma(T) = [\frac{1}{N}\sum(\delta T - \overline{\delta T})^2]^{1/2}$

- 2 point correlation function

$$C_{TT}(\gamma) = \frac{1}{N^2}\left[\sum \delta T(\hat{n})\delta T(\hat{n'}) - \sum \delta T(\hat{n}) \times \sum \delta T(\hat{n'})\right]$$

Measure based on STD

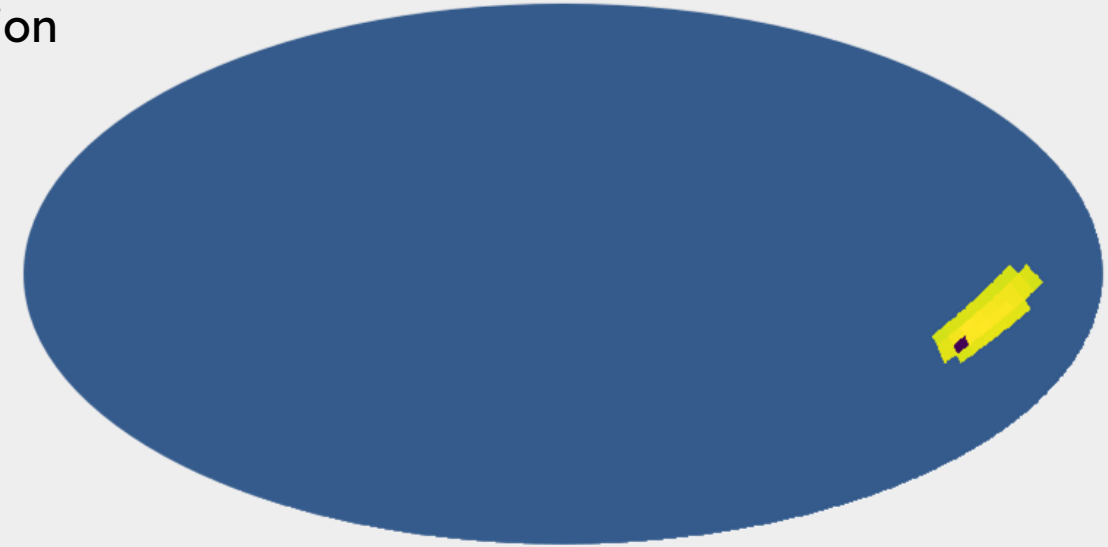
$$\sigma_{top}(T)$$

$$[\sigma_{top}(T) - \sigma_{bottom}(T)]^2$$

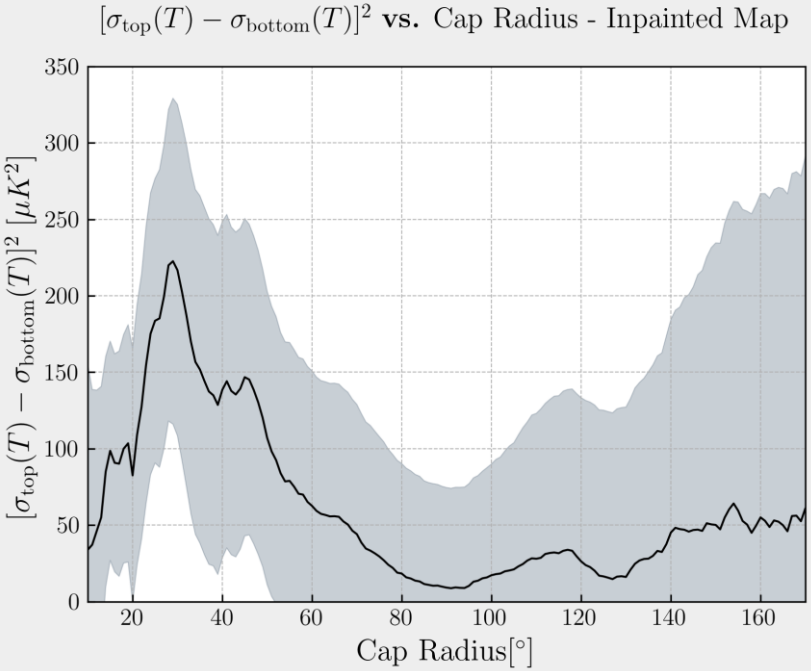
Which Direction?

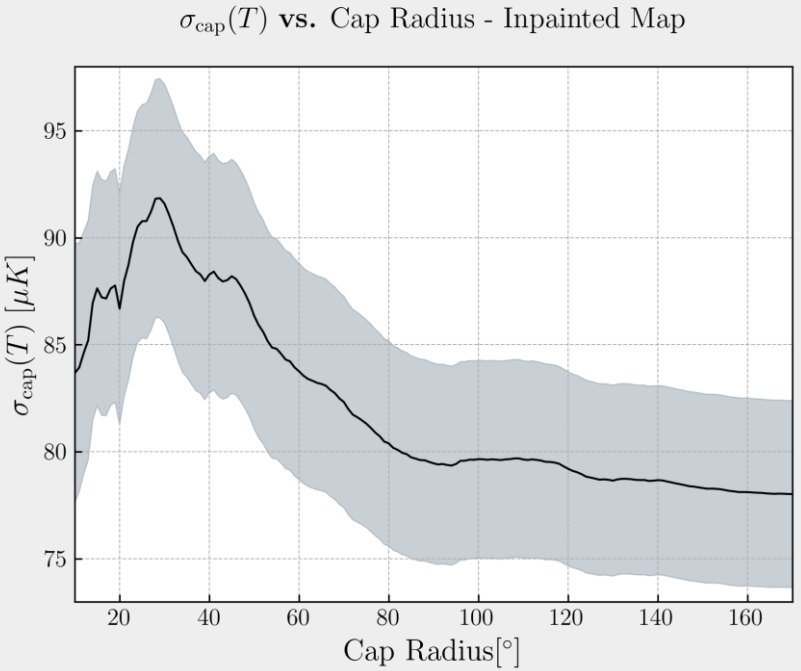
- Caps of 10 to 90 deg radius
- Different Probes $\longrightarrow \sigma_{top}(\boldsymbol{T})$
- Consistency with the direction reported by Planck (lon = 221, lat = -20)

Direction of study for CMB

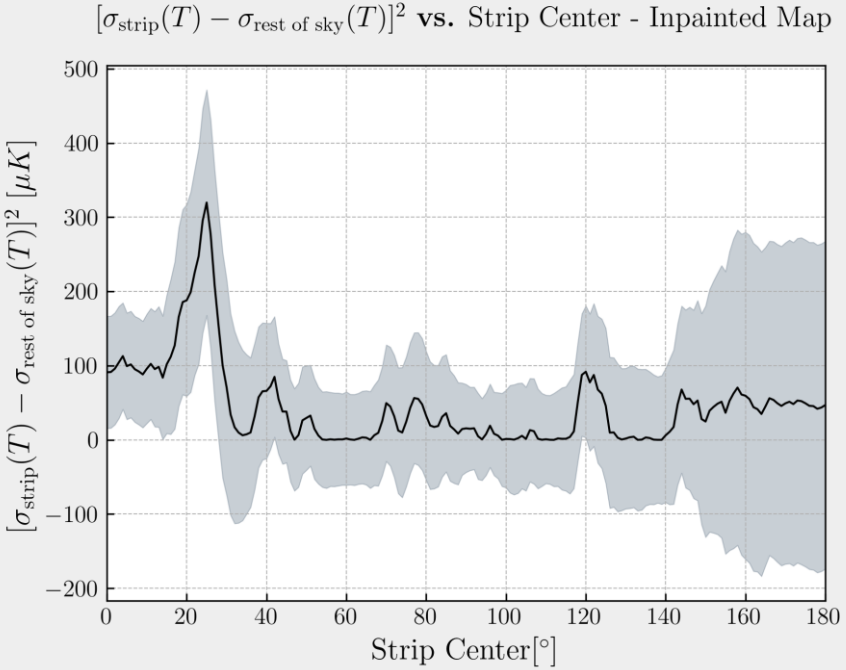


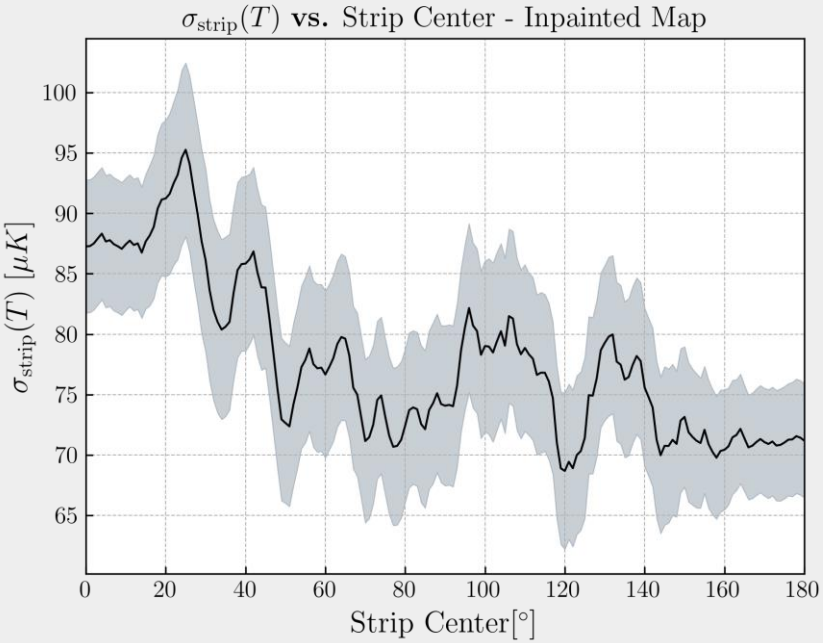
Results For Caps





Results For Strips



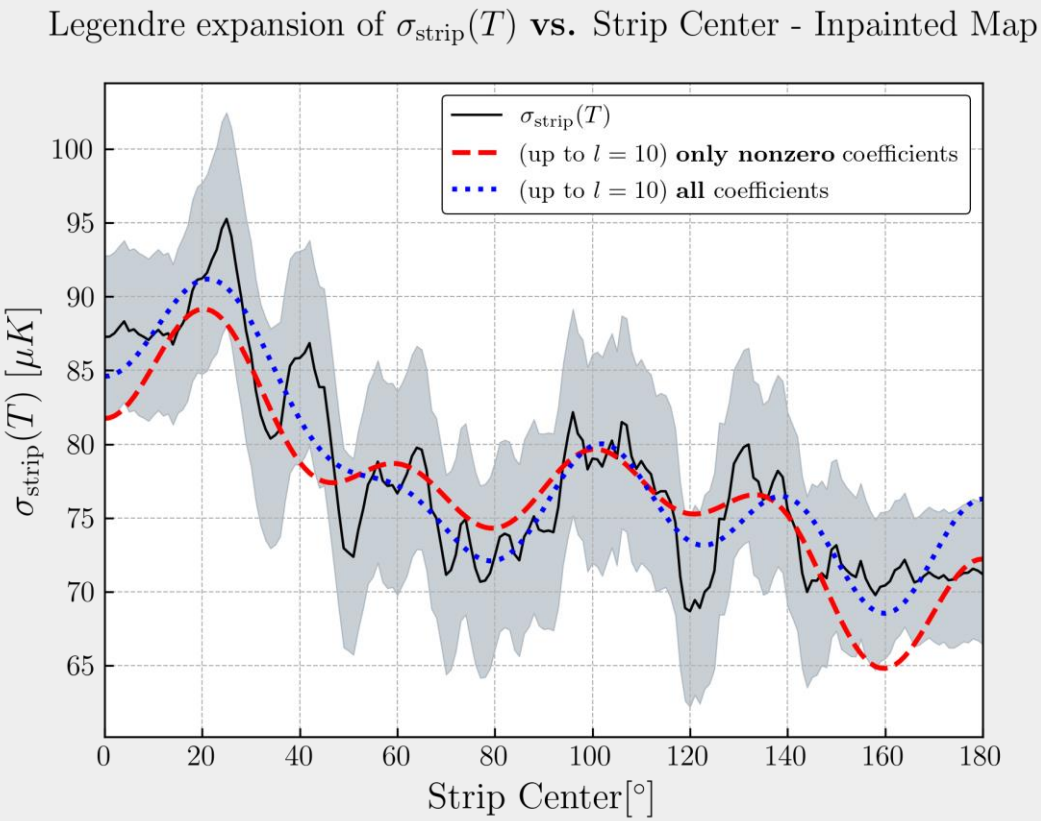


$$\Delta z = 1 - \cos(20^\circ)$$

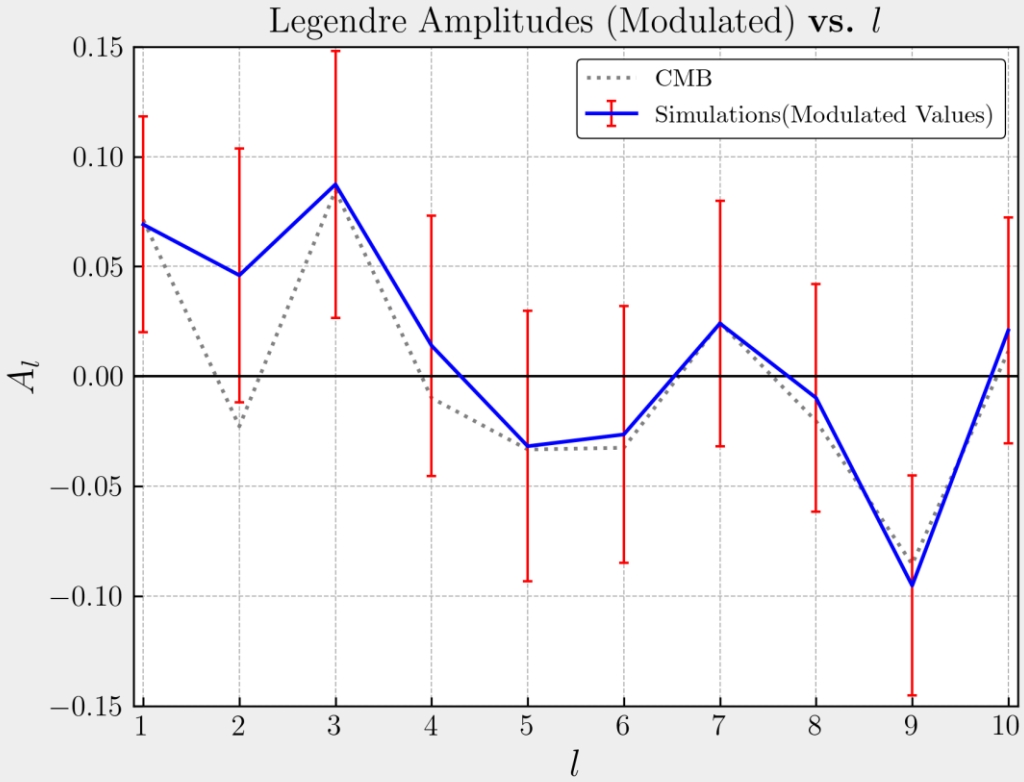
Multipoles

$$\sigma_T|_{mod}(\theta) =$$

$$\sum_{l=0} A_l P_l(\cos\theta)\sigma_T|_{iso}(\theta)$$



Multipoles



$$\Delta T|_{mod}(\hat{n}) = (1 + A\hat{n}.\hat{p})\Delta T|_{iso}(\hat{n})$$

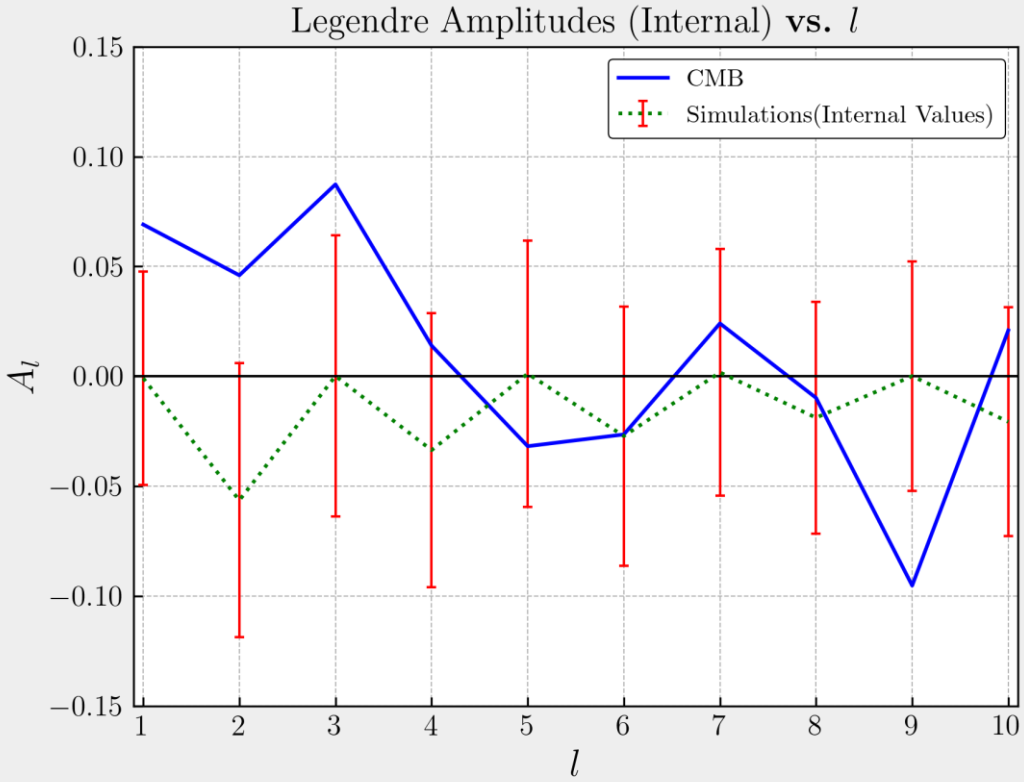
$$\Delta T|_{mod}(\hat{n}) = (1 + AP_1(\hat{n}.\hat{p}))\Delta T|_{iso}(\hat{n})$$

$$\sigma_T|_{mod}(\theta) = \sum_{l=0} A_l P_l(\cos\theta)\sigma_T|_{iso}(\theta)$$

If z is along p: $\hat{n}.\hat{p} = \cos\theta = z$

$$\Delta T|_{mod}(\hat{n}) = \sum_{l=0} A_l P_l(z)\Delta T|_{iso}(\hat{n})$$

Multipoles



Internal values of simulations in the most anomalous direction (with 30° cap)

Summary

- Theoretical questions around dipole
- Taking simple shapes and windows to measure statistics in finer structures
- Adding modulation to simulations using Legendre expansion, Reading errors & significance
- With the statistical measures, dipole is not enough to describe the directional anomaly

Thank You!

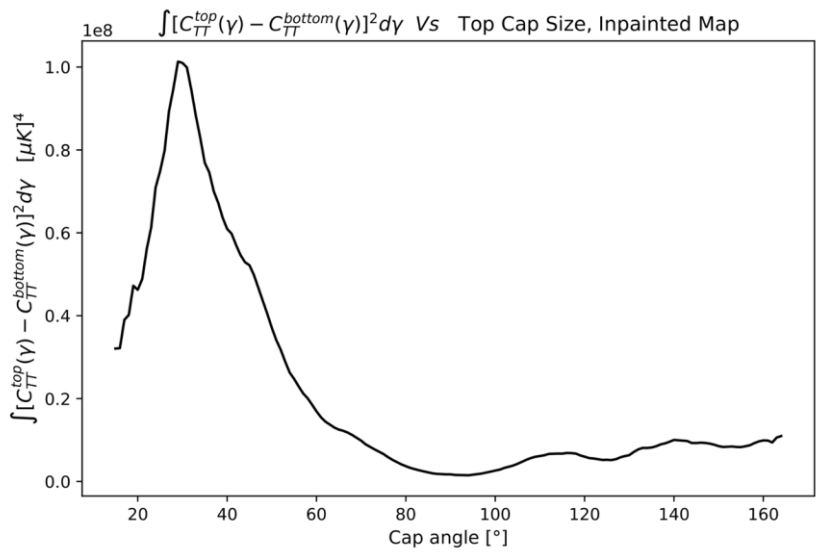
Everything is isotropic!

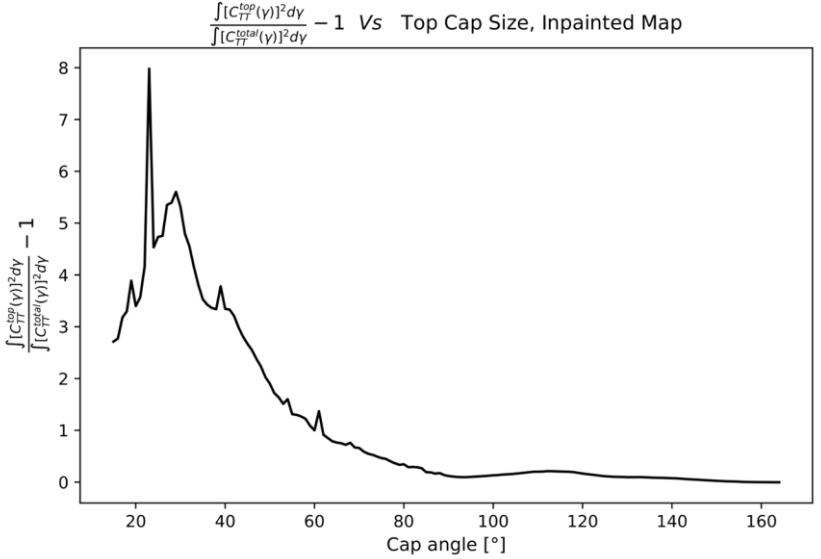
Measures based on 2PCF

$$\frac{\int C_{TT}^{top}(\gamma)d\gamma}{\int C_{TT}^{bottom}(\gamma)d\gamma} - 1$$

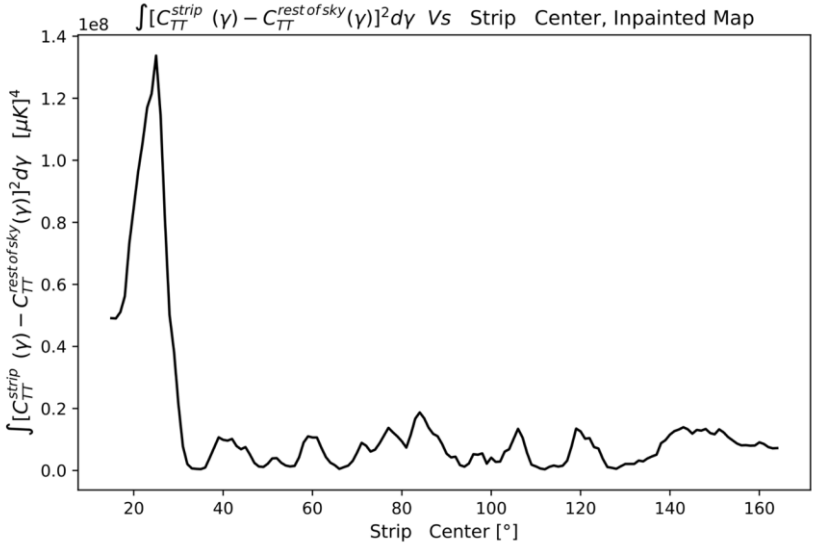
$$\int \left[C_{TT}^{top}(\gamma) - C_{TT}^{bottom}(\gamma)\right]^2 d\gamma$$

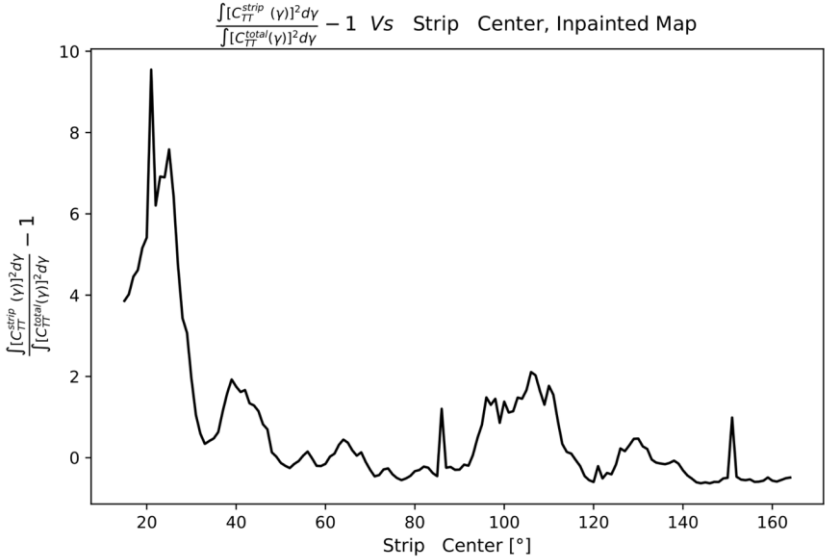
Results For Caps





Results For Strips





$$\Delta z = 1 - \cos(20^\circ)$$