Degree Scale Anomalies in the CMB:

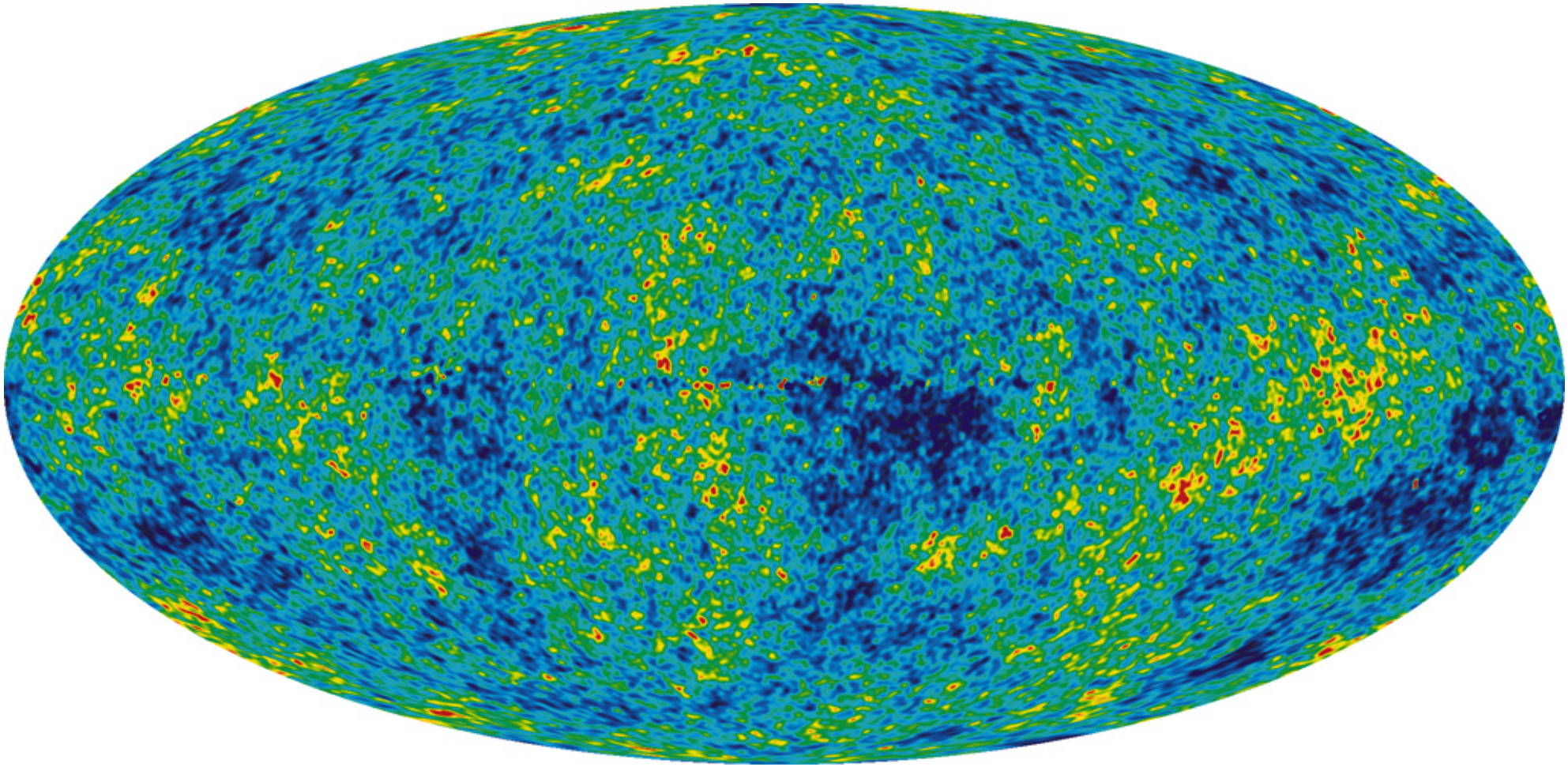
Localizing the First Peak Dip to a Small Patch of the North Ecliptic Sky

Amanda Yoho[1], Francesc Ferrer[2], and Glenn Starkman[1]

[1]Case Western Reserve University
[2]Washington University, St. Louis

arxiv.org:1005.5389

The WMAP Sky



Credit: WMAP/NASA Science Team

- Temperature maps are decomposed into spherical harmonics and their coefficients

$$\Delta T(\mathbf{n}) = \sum_{l>0} \sum_{m=-l}^{l} a_{lm} Y_{lm}(\mathbf{n})$$

- The coefficients can be written in terms of the temperature fluctuations

$$a_{lm} = \int d\Omega_{\mathbf{n}}\, \Delta T(\mathbf{n}) Y^*_{lm}(\mathbf{n})$$

- If the coefficients are gaussian, we can exploit their properties to find the power spectrum

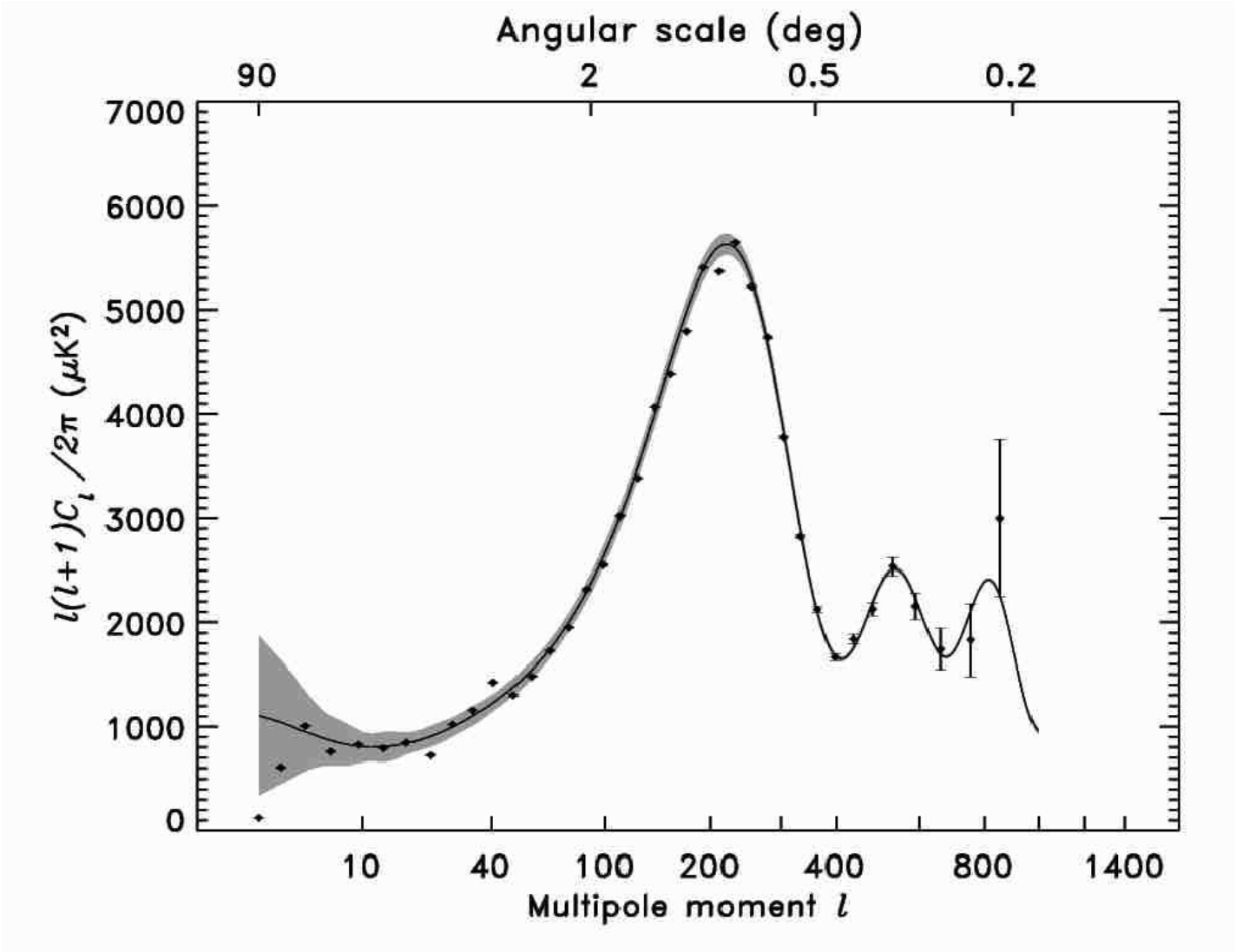
$$\langle a_{lm} \rangle = 0$$

$$\langle a_{lm} a^*_{l'm'} \rangle = \delta_{ll'}\, \delta_{mm'}\, C_l$$

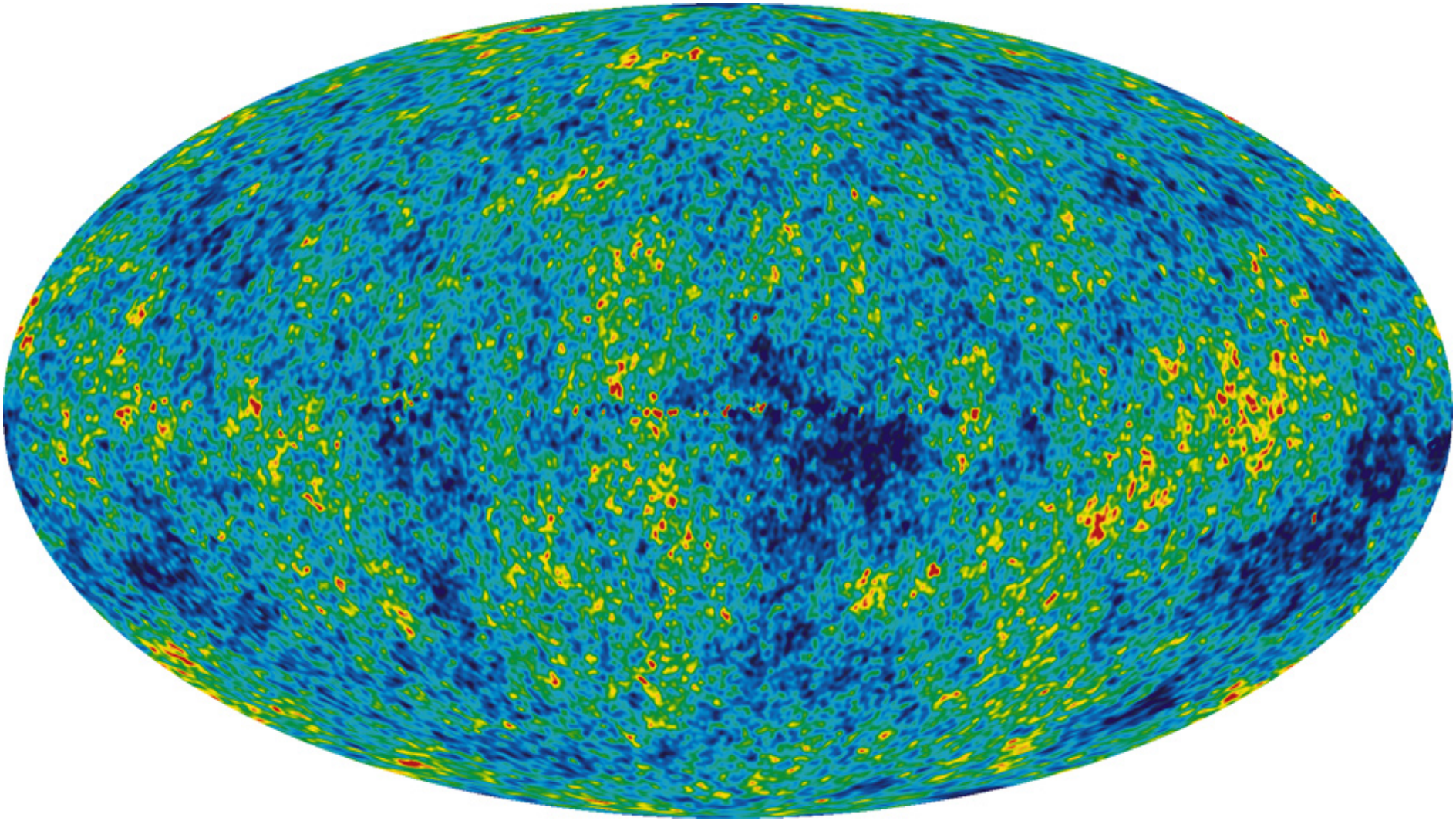
- We can rewrite the C_l's in terms of the coefficients and use them to plot the power spectrum

$$C_l^{\mathrm{sky}} = \frac{1}{2l+1} \sum_{m=-l}^{l} |a_{lm}|^2$$

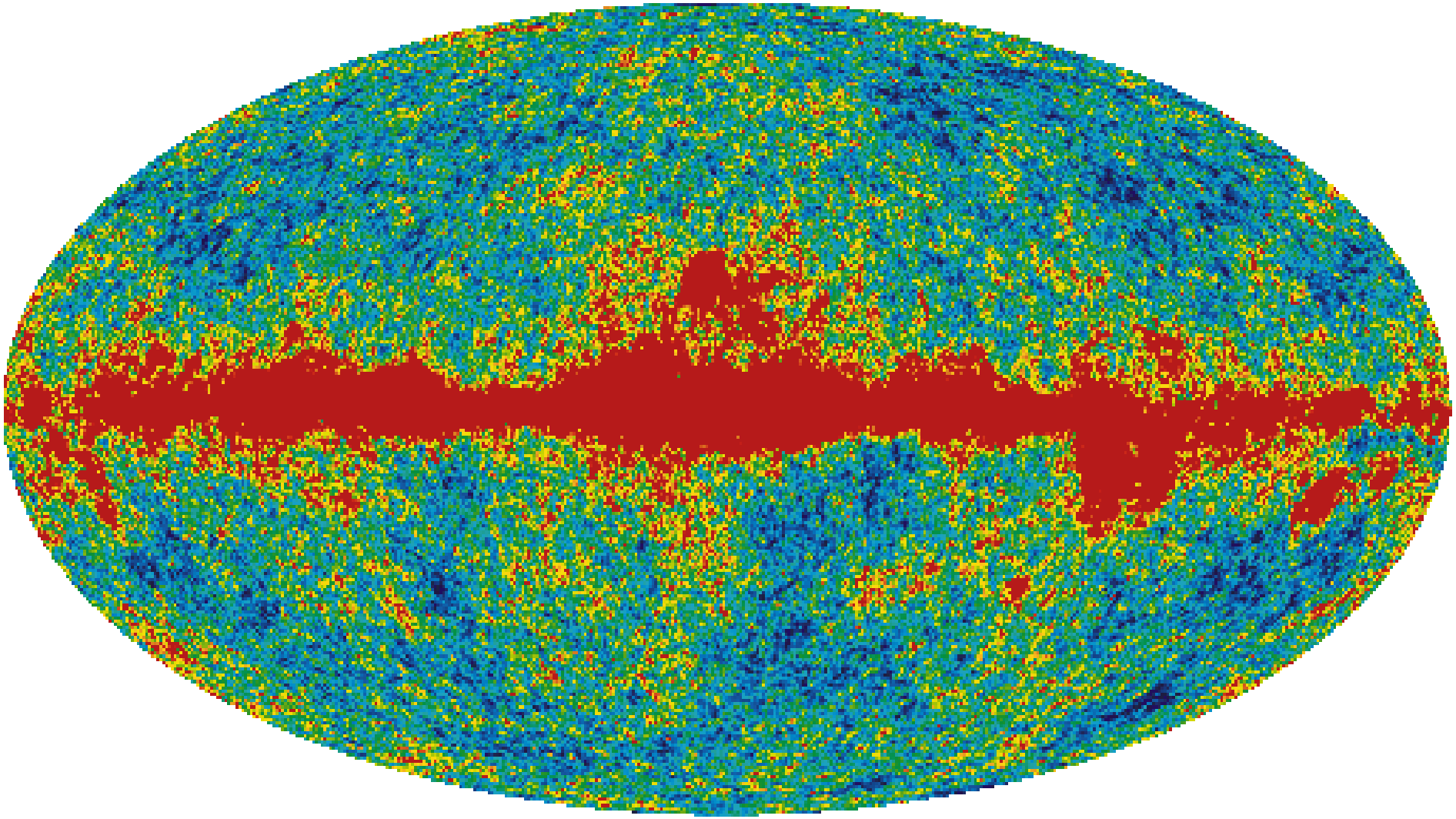
The Angular Power Spectrum



Hinshaw 2003



Credit: WMAP/NASA Science Team



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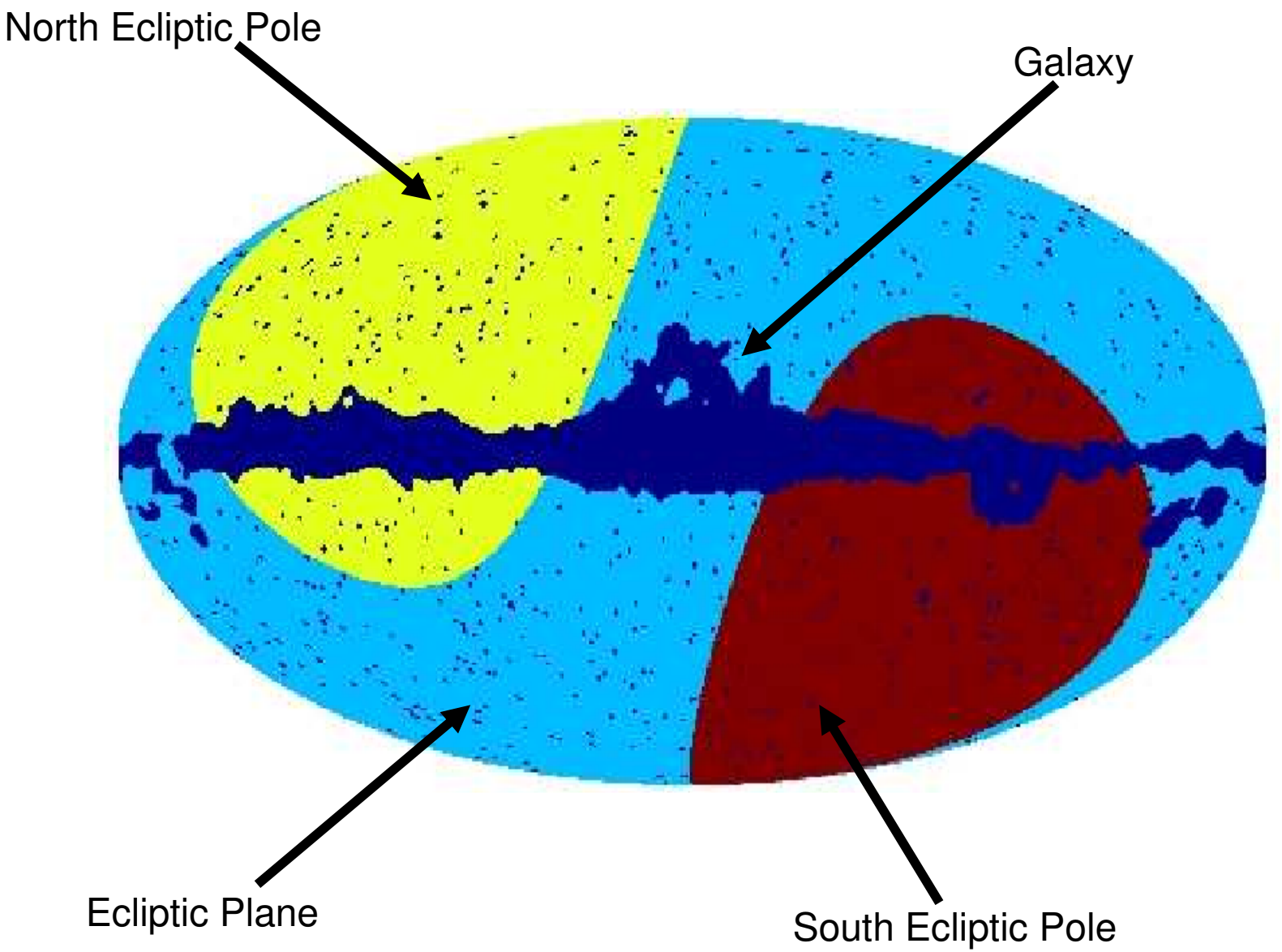
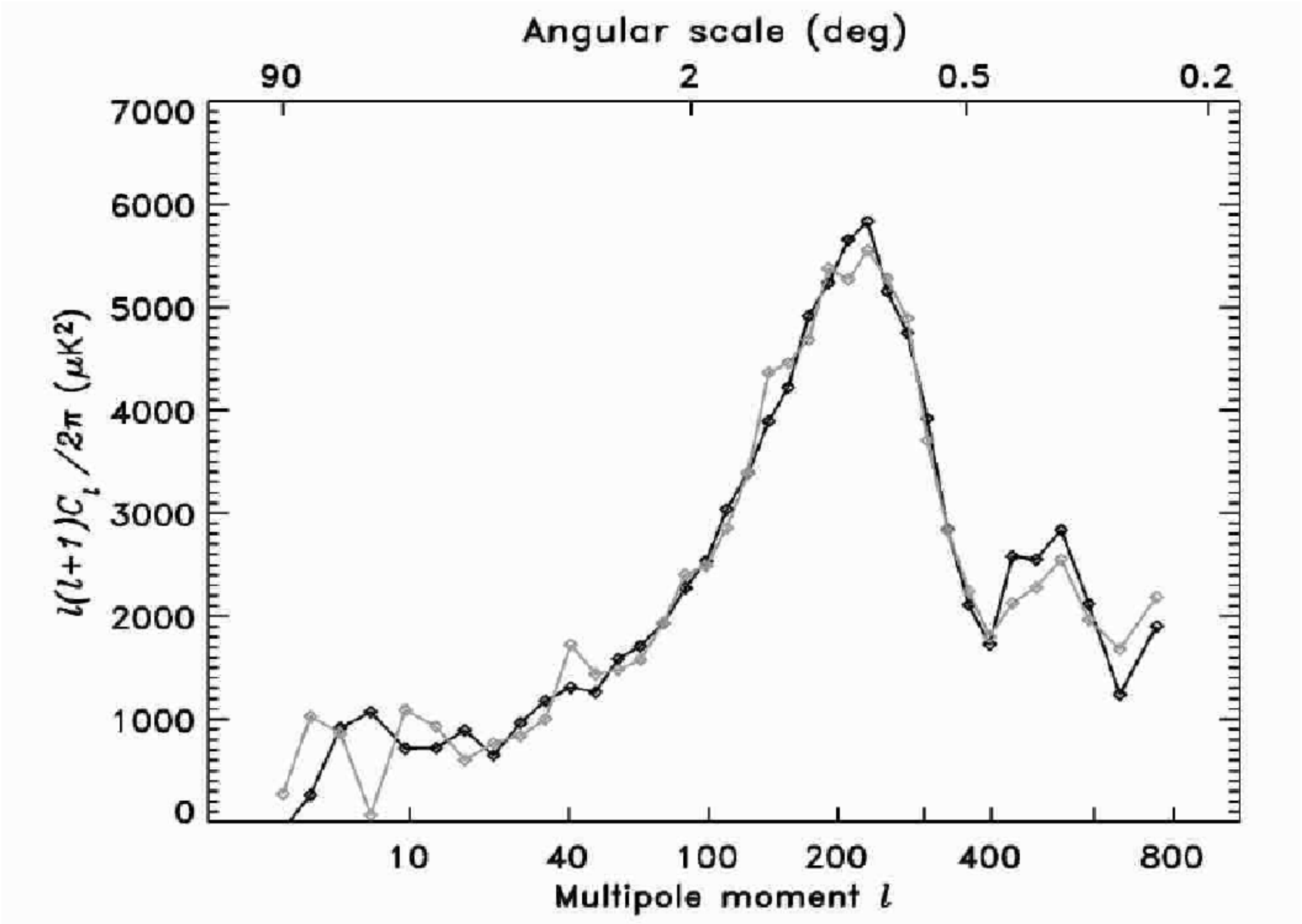

North Ecliptic Pole
Galaxy
Ecliptic Plane
South Ecliptic Pole



Gray – Data from the poles
Black – Data from the plane

Hinshaw 2003

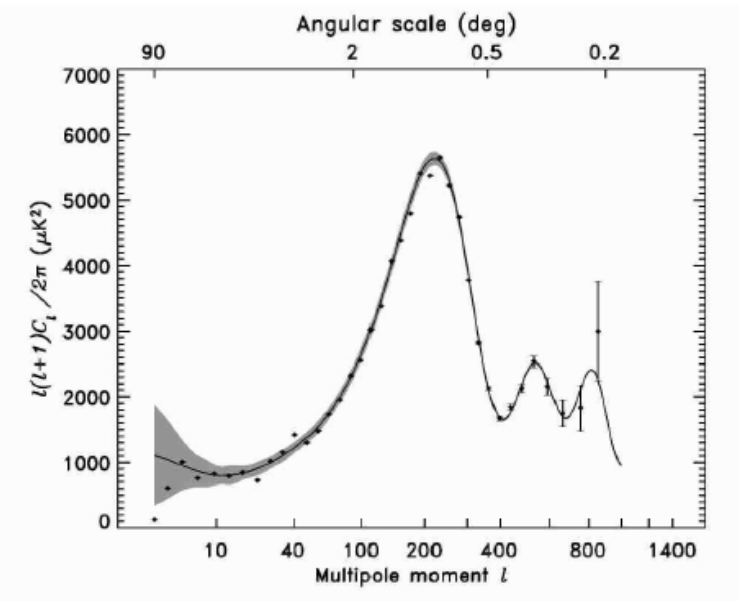
Changes to 1st year analysis

- Beam transfer function changed
- Additional point sources masked out
- Map weighting scheme changed

1st year power spectrum

For $200 < l < 450$

$$W(p) = \frac{M(p)}{1/\langle N_{\rm obs}\rangle + 1/N_{\rm obs}(p)}$$

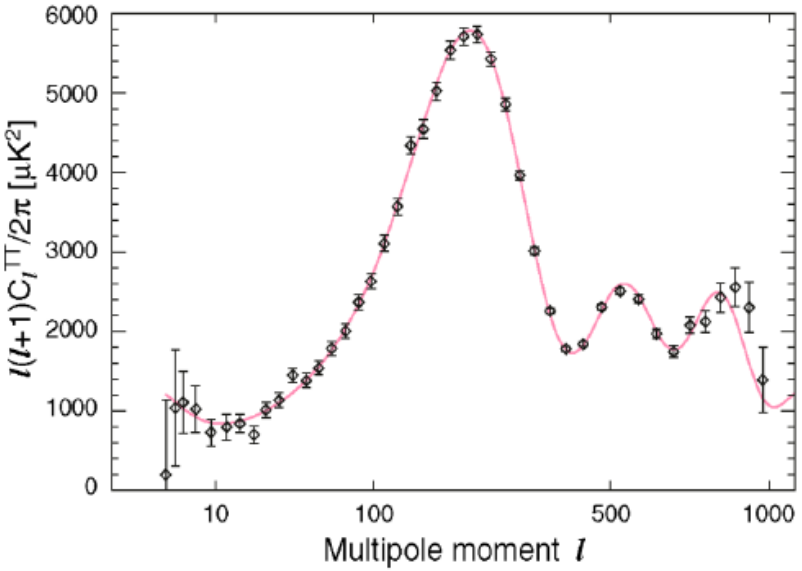


Hinshaw et al. 2003

3rd year power spectrum and beyond

$$l = 500$$

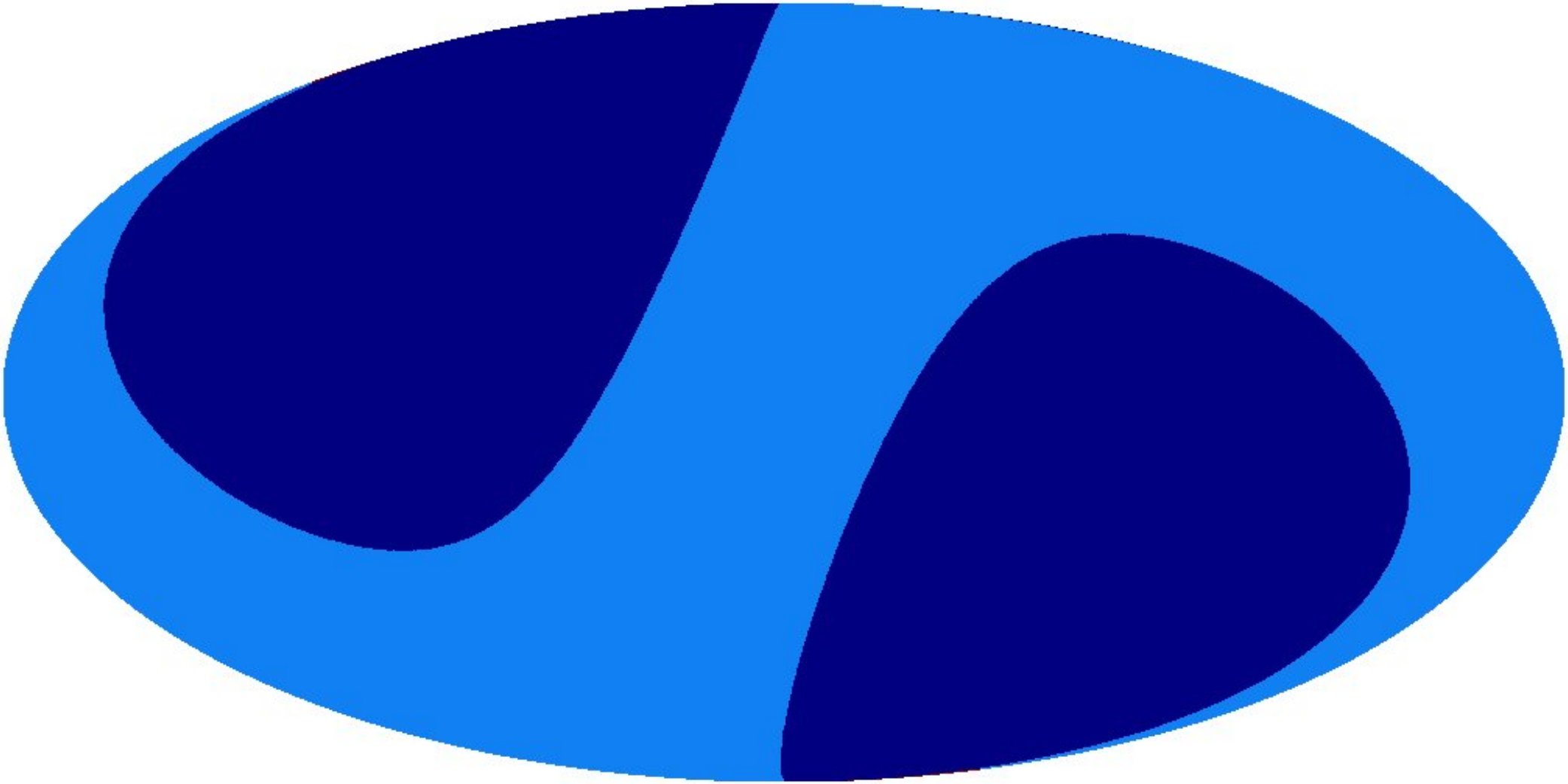
$$W(p) = M(p)$$

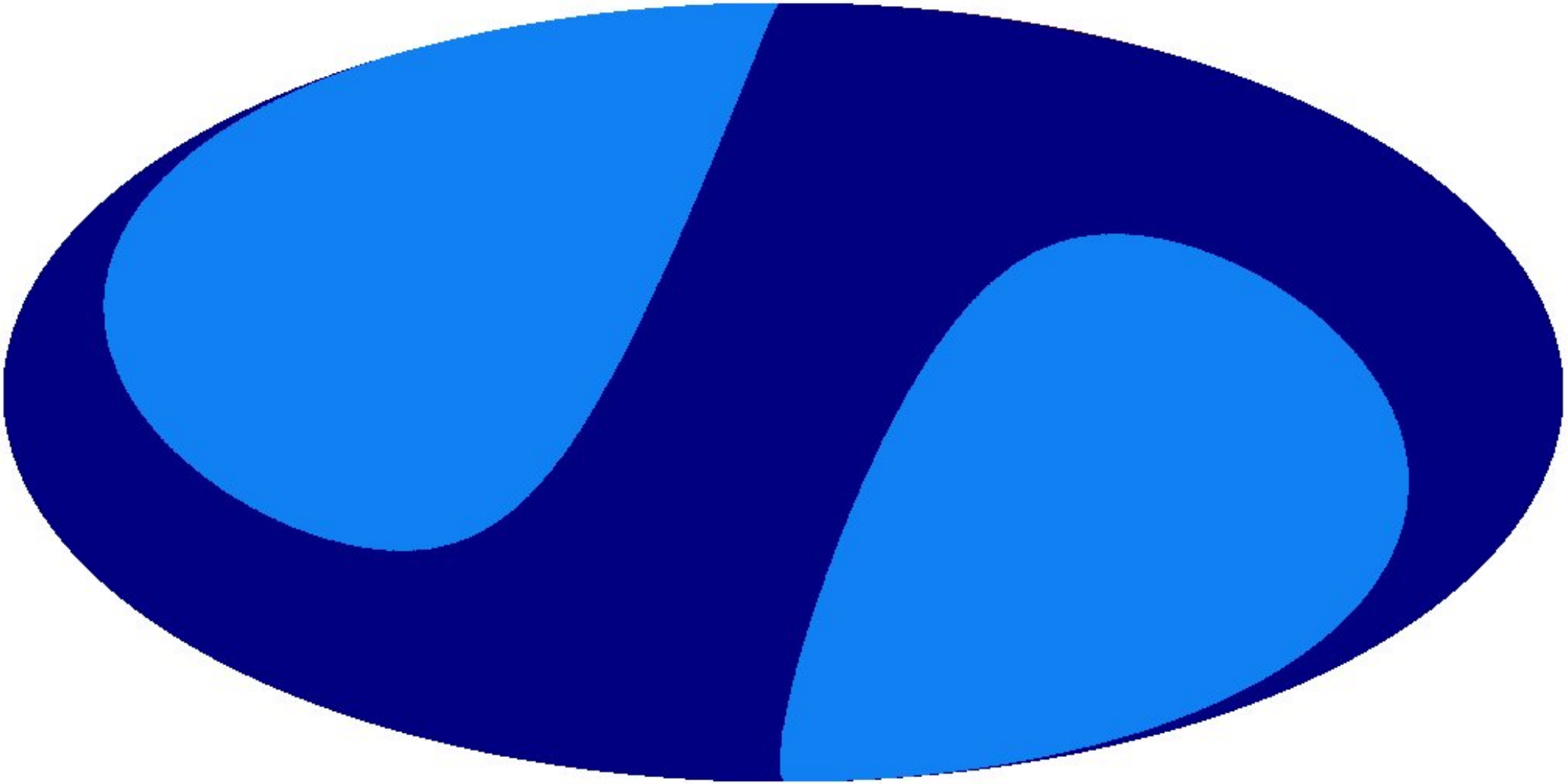


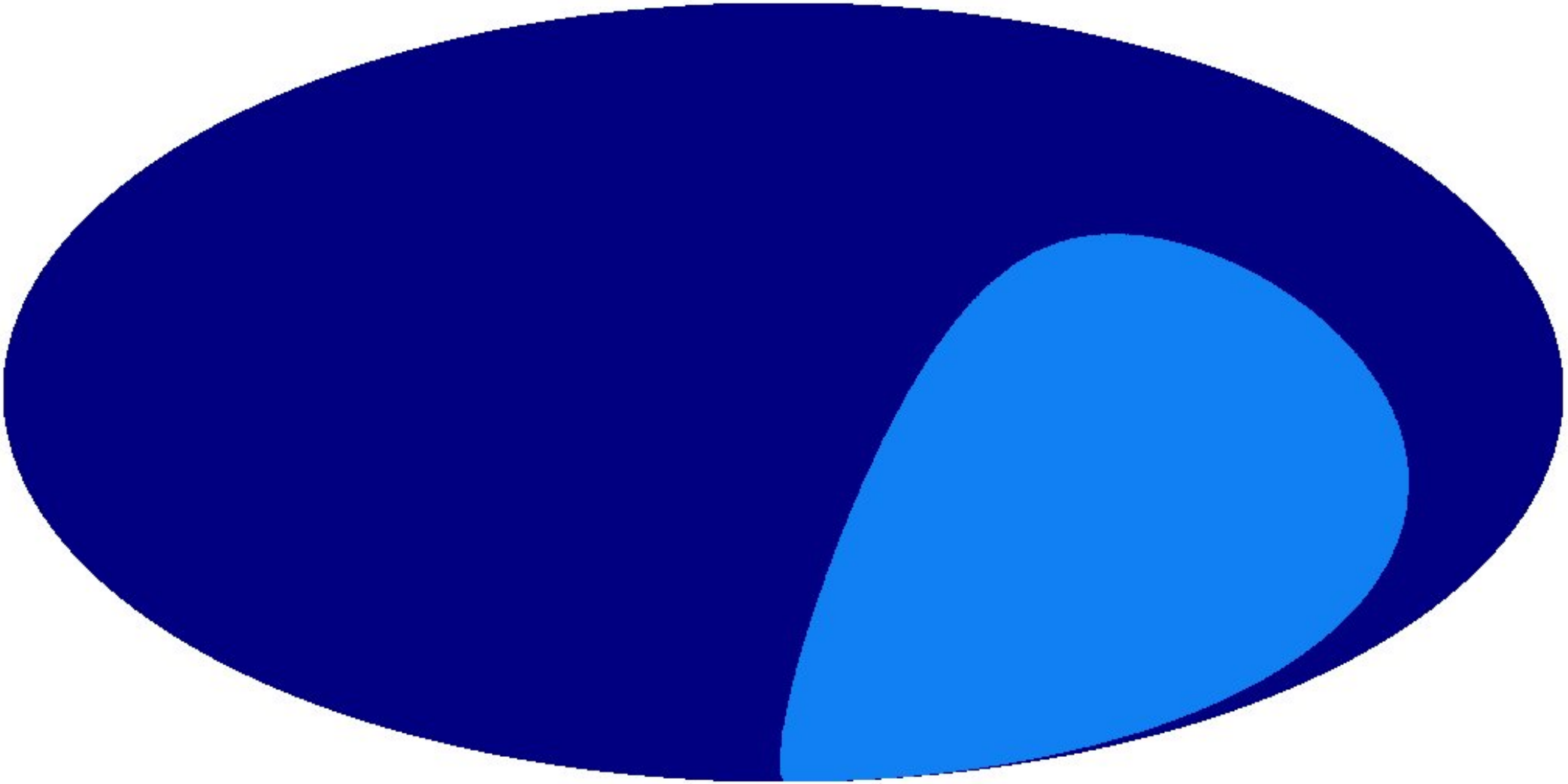
Nolta et al. 2008

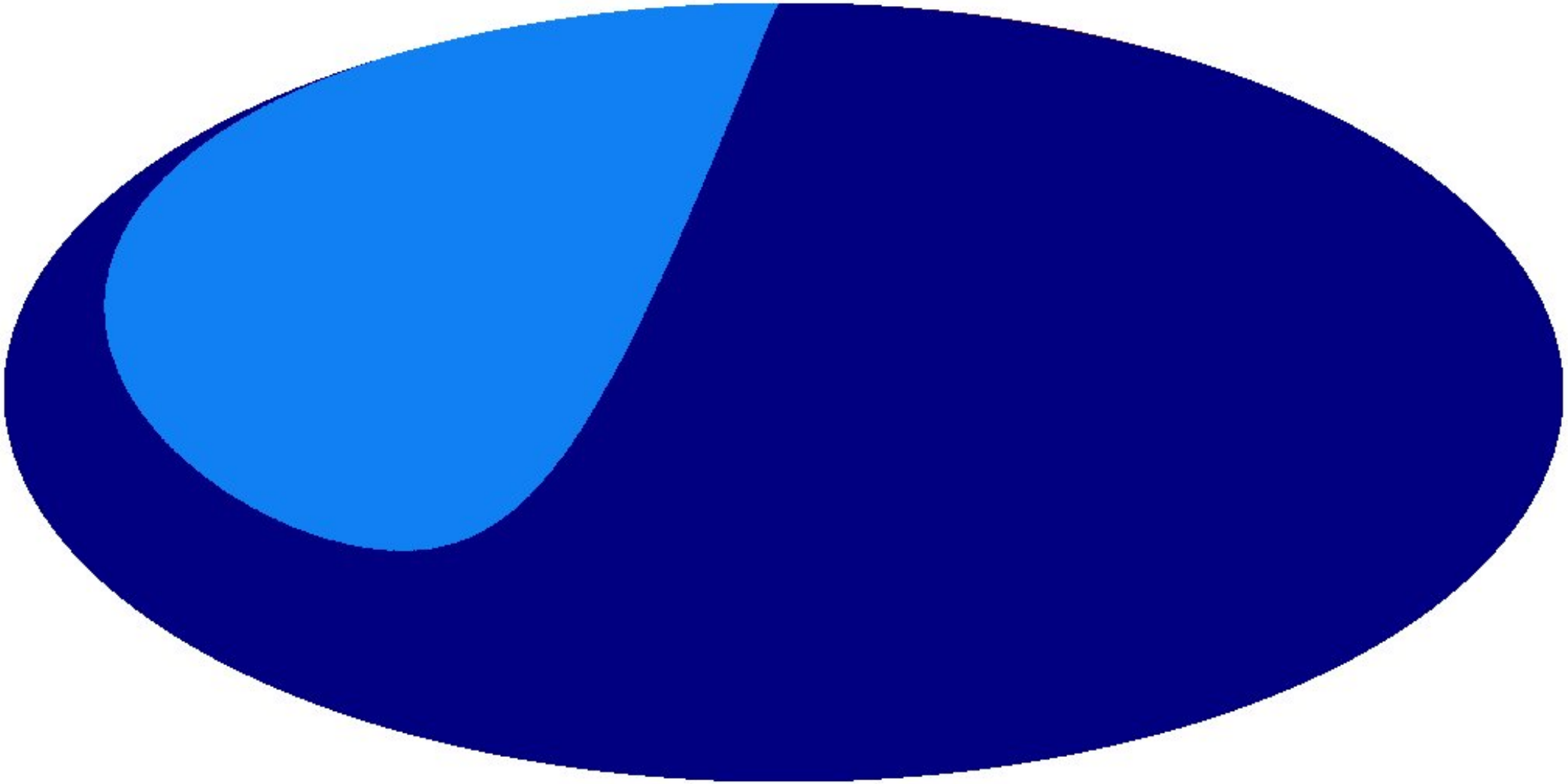
The Game Plan

- Mask different regions of the WMAP skies (specifically the north and south ecliptic poles)
- Calculate the corresponding power spectra
- Generate 10,000 realistic random LCDM skies
- Use random maps to determine statistical significance



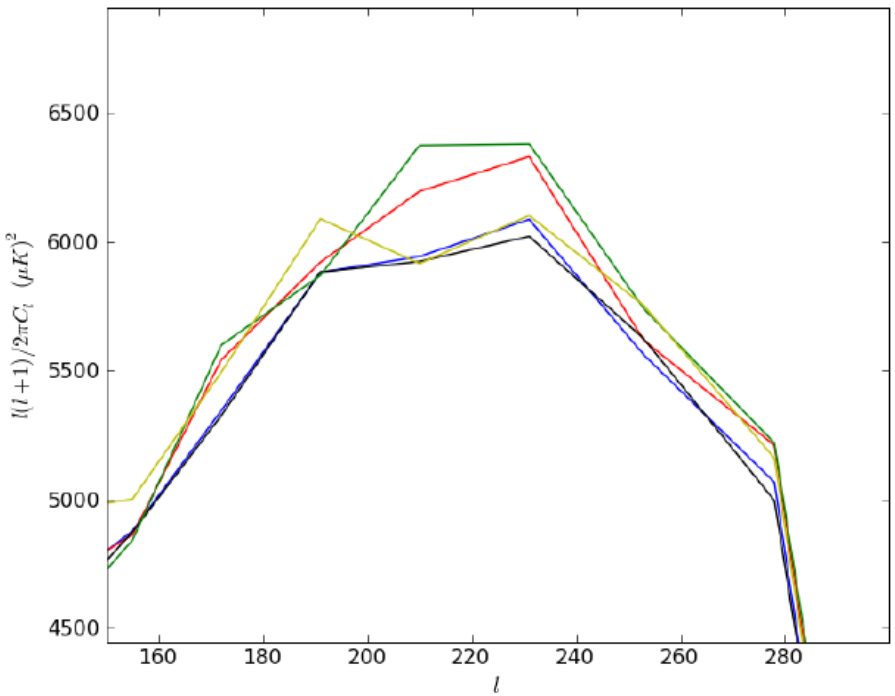




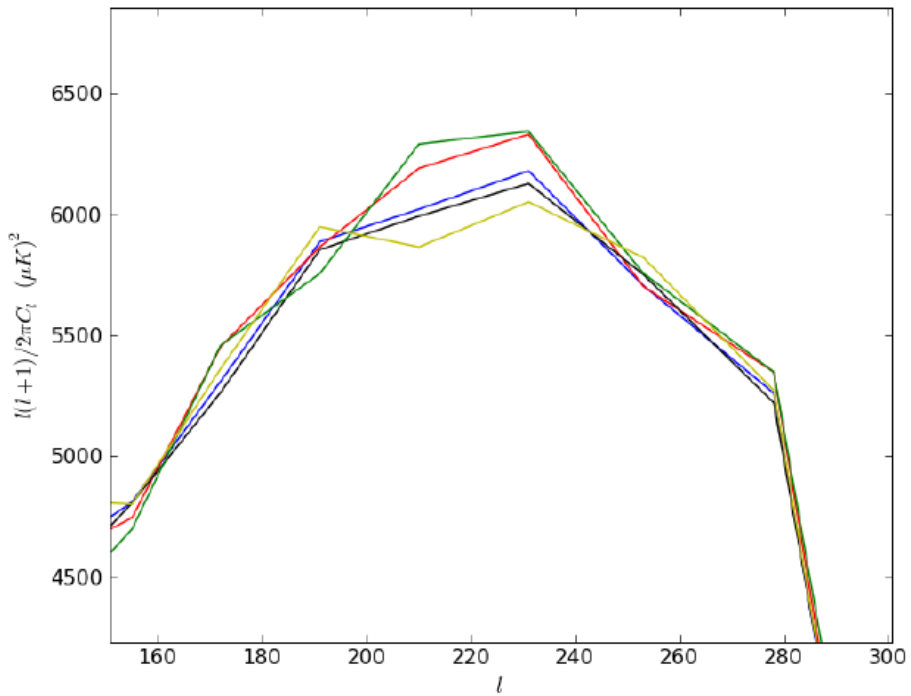


First year data

First year weighting



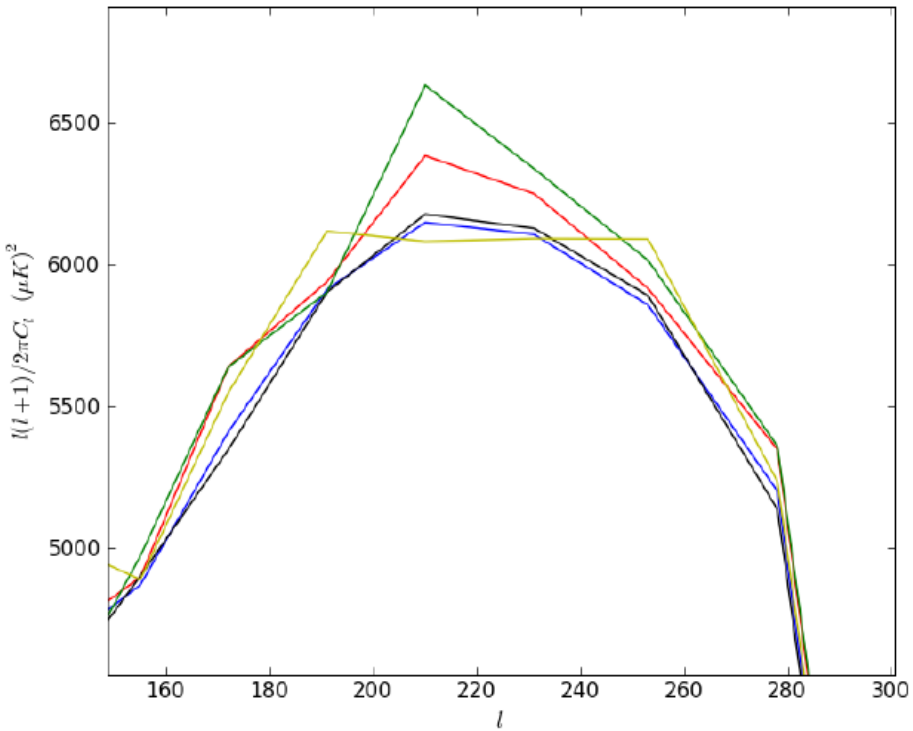
Third year weighting



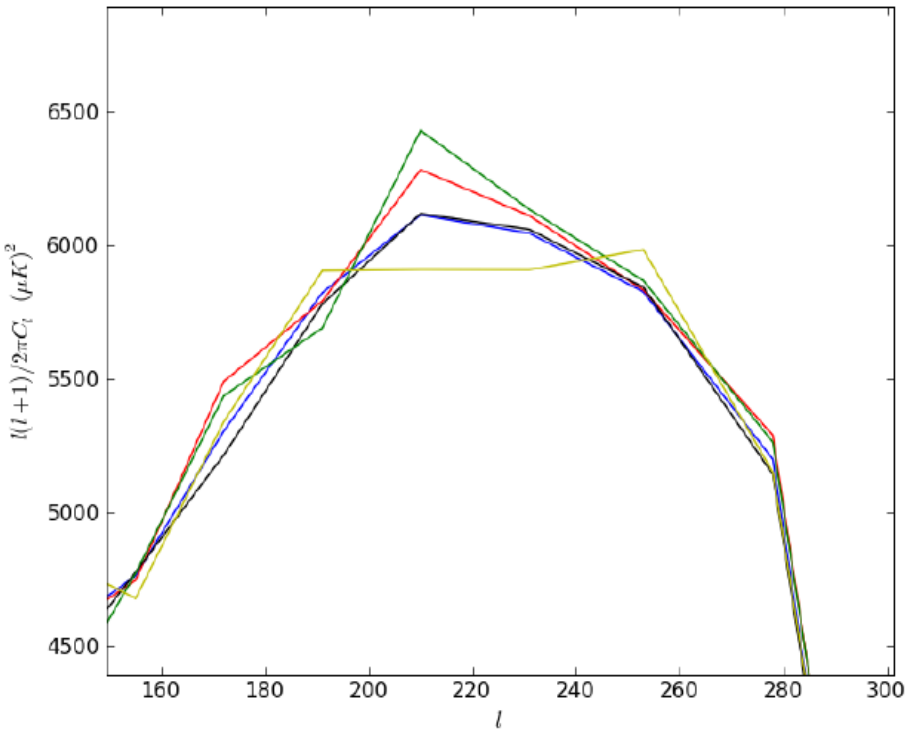
Shown are the full sky (blue), full sky without the north (red) and south (black) ecliptic caps, the ecliptic plane only (green), and the ecliptic poles only (yellow). The galaxy is always masked out.

Third year data

First year weighting



Third year weighting



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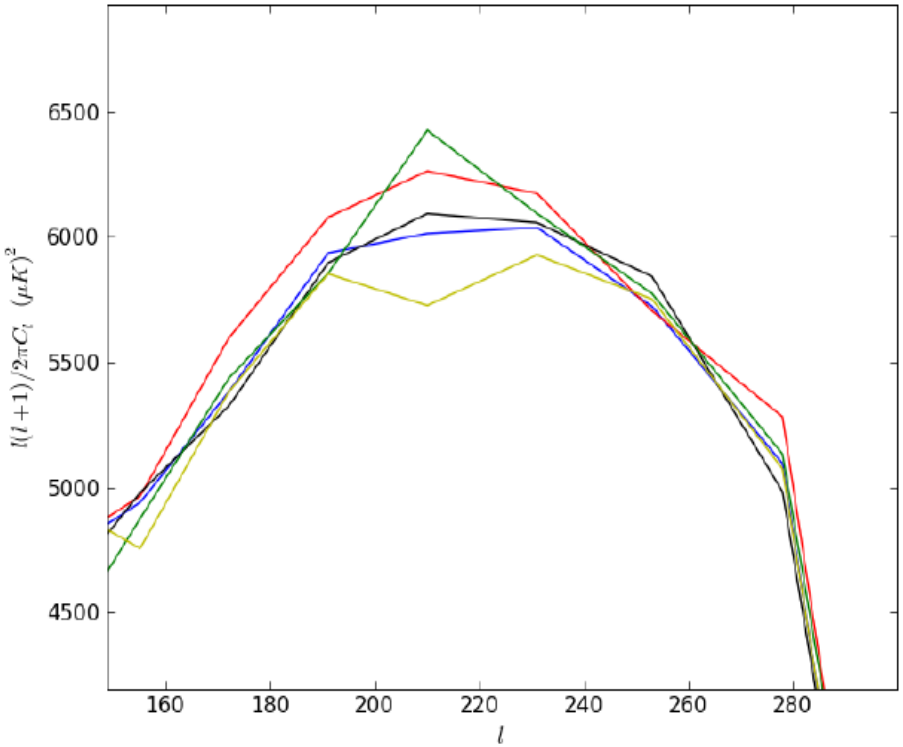
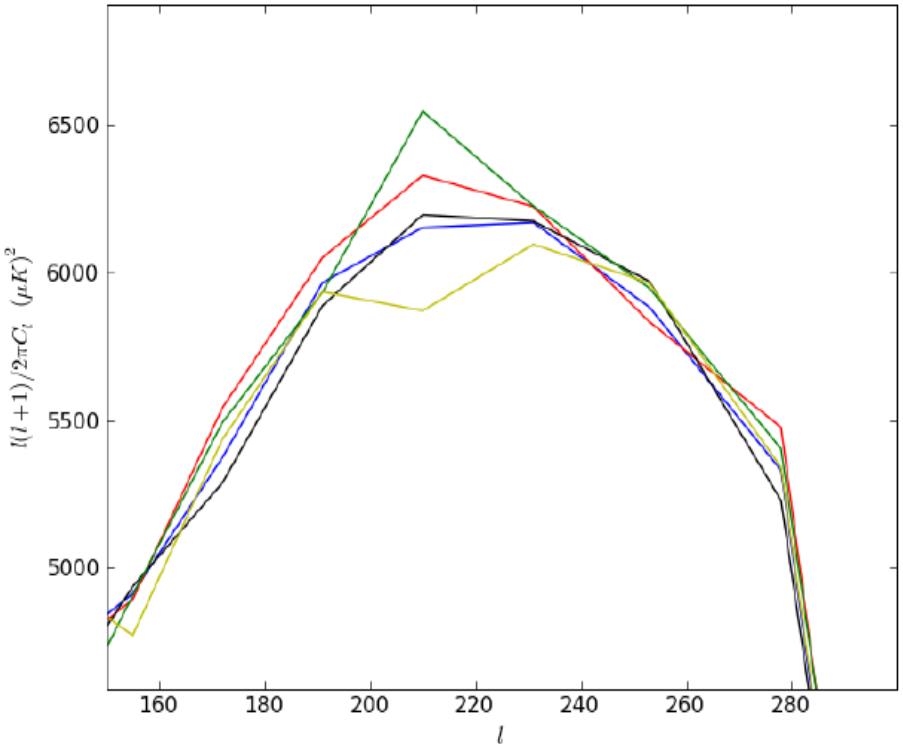
Fifth year data

First year weighting



Third year weighting



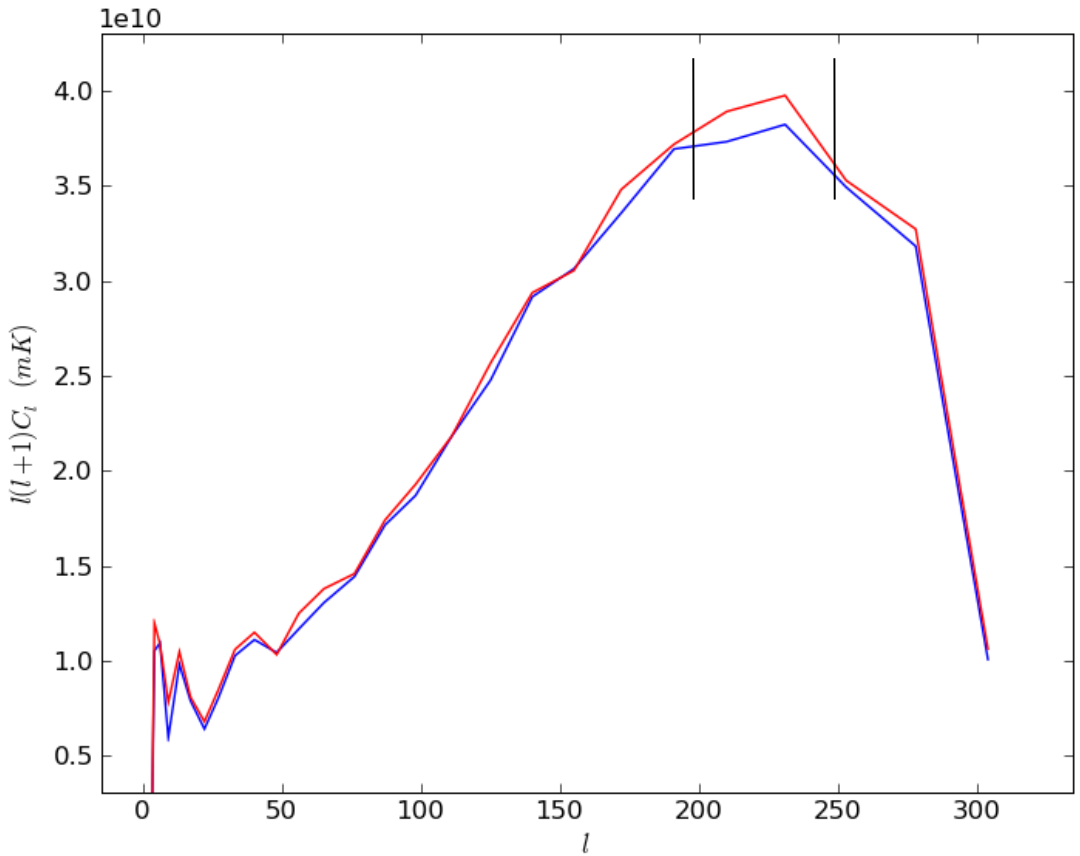
Shown are the full sky (blue), full sky without the north (red) and south (black) ecliptic caps, the ecliptic plane only (green), and the ecliptic poles only (yellow). The galaxy is always masked out.

Simulated Sky Maps

- Generate a random set of $a_{\ell m}$ from input LCDM power spectrum
- Make map from $a_{\ell m}$
- Make map more “realistic” by adding
  - Pixel noise
  - Beam transfer function
- Use realistic sky maps to calculate peak statistic

Peak Statistic

$$S_{\rm peak} \equiv 2\frac{\sum_{\ell=\ell_{min}}^{\ell_{max}}\left(C_\ell^{KQ85+add'l\ mask} - C_\ell^{KQ85}\right)}{\sum_{\ell=\ell_{min}}^{\ell_{max}}\left(C_\ell^{KQ85+add'l\ mask} + C_\ell^{KQ85}\right)}$$



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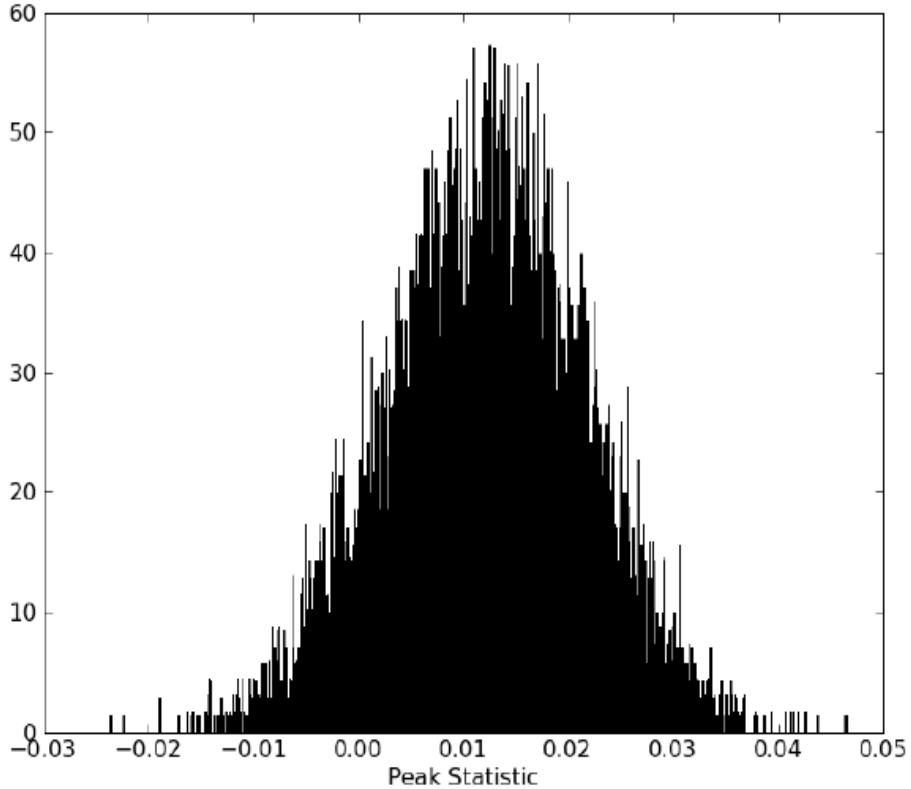
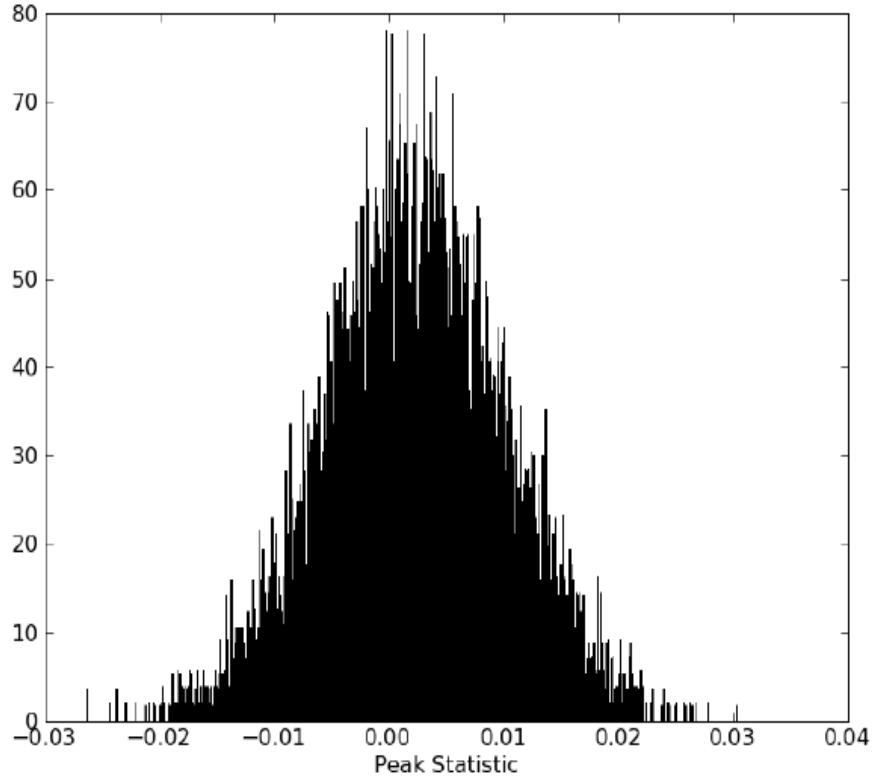
First year weighting



Third year weighting



	1st year weighting		3rd year weighting	
1-year	.0347	99.52%	.0206	99.35%
3-year	.0274	95.78%	.0166	97.47%
5-year	.0278	96.23%	.0154	96.24%

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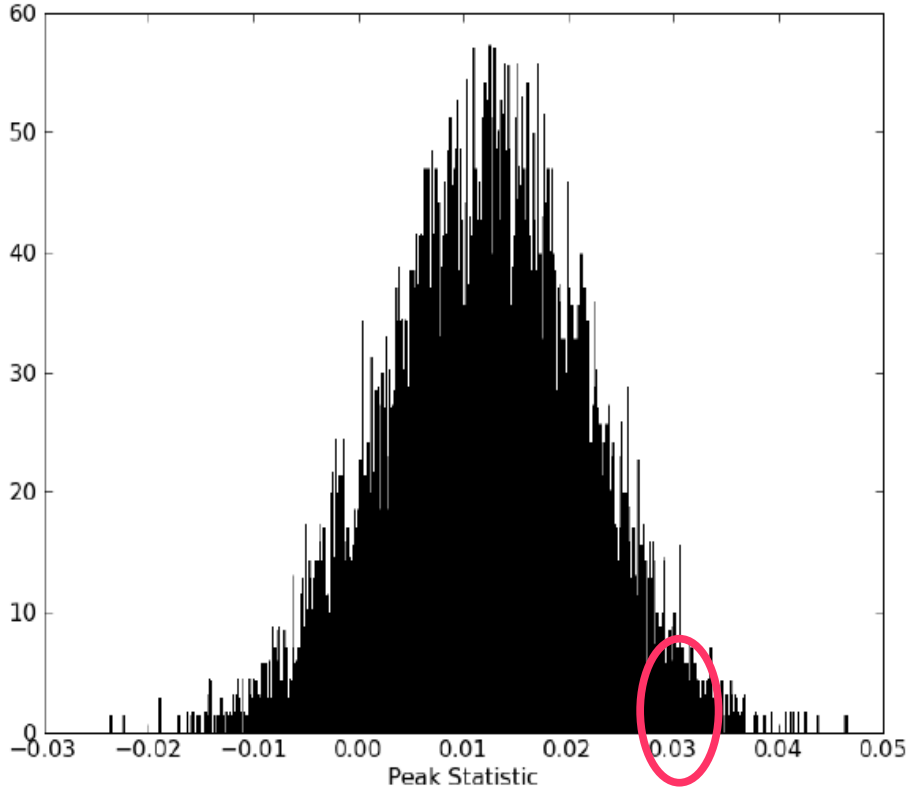

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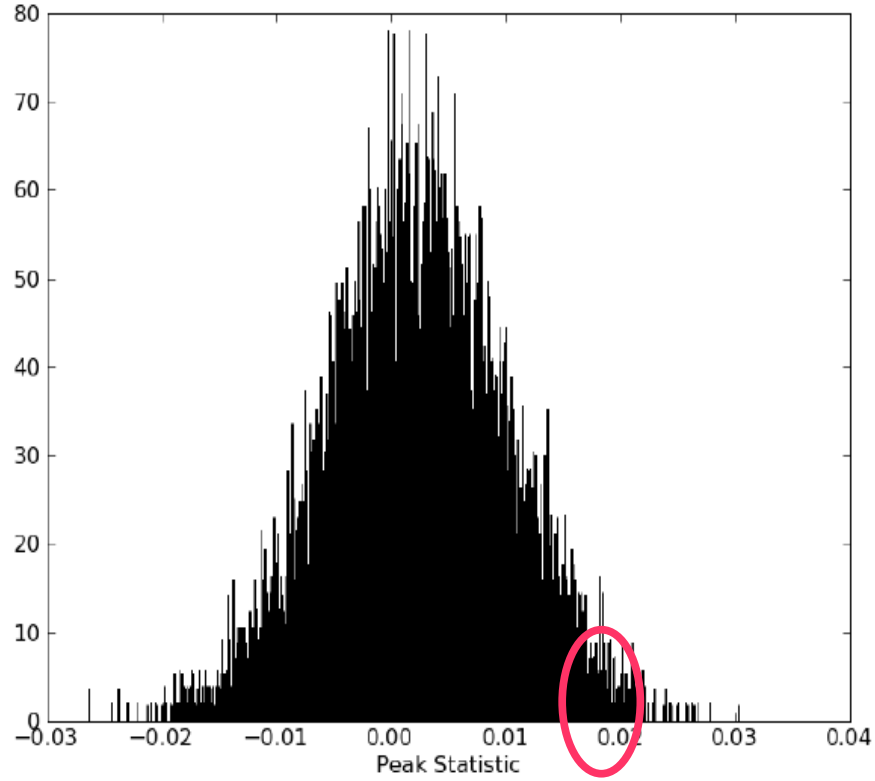

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Conclusions

- WMAP claims that decrease in power went away after first year, despite changes in weighting scheme
- We find that using the data from the north ecliptic pole decreases the power of the CMB across all data releases
- This increase is significant to above 96% in the 5th year release

Future Work

- Use 7 year data for analysis
- Look at modulation of other anomalous points
- Planck
- Check modulation around the sky