Pre-Inflationary Relics and Large Scale Anomalies

Ely D. Kovetz
University of Texas at Austin
Aspen Winter 2012, January 31st

Based on:

A. Ben-David, EDK and N. Itzhaki, “Parity in the CMB: Space Oddity”, ApJ, to appear 2012. arXiv:1108:1702

EDK, A. Ben-David and N. Itzhaki, “Giant Rings in the CMB Sky”, ApJ 724, 2010. arXiv:1005.3923

A. Fialkov, N. Itzhaki and EDK, “Cosmological Imprints of Pre-Inflationary Particles”, JCAP 2010, arXiv:0911.2100

Outline

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- Motivation: Pre-Inflationary Physics

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- Pre-Inflationary Particle - Signatures

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- Observational Tests: CMB Rings, Bulk Flow, Mirror Parity.
- Fitting a model to the data

ΛCDM Universe

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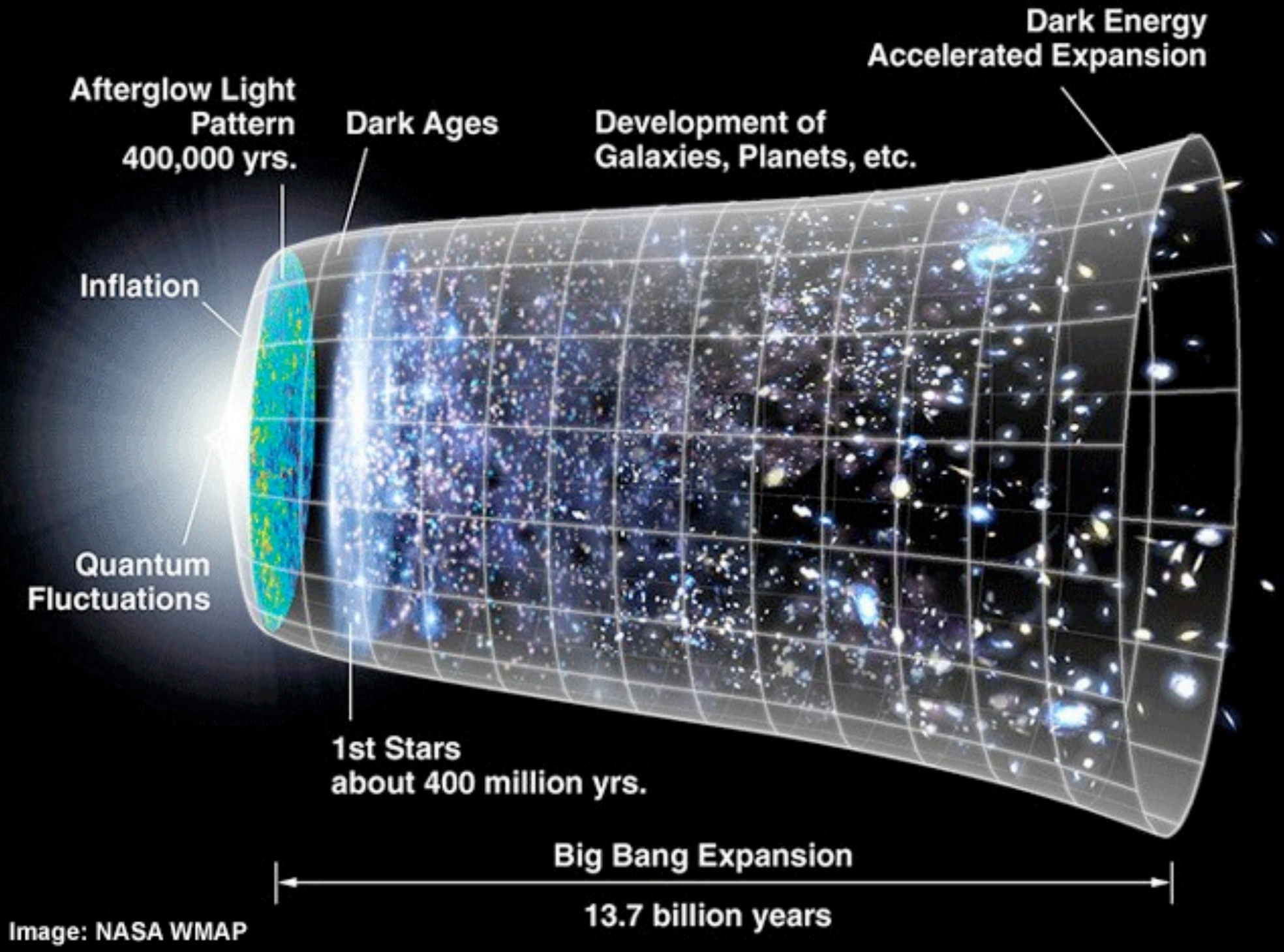

Pre-Inflationary Particle - Model

(Fialkov, Itzhaki, EDK, JCAP 2010)

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PIP - Signatures

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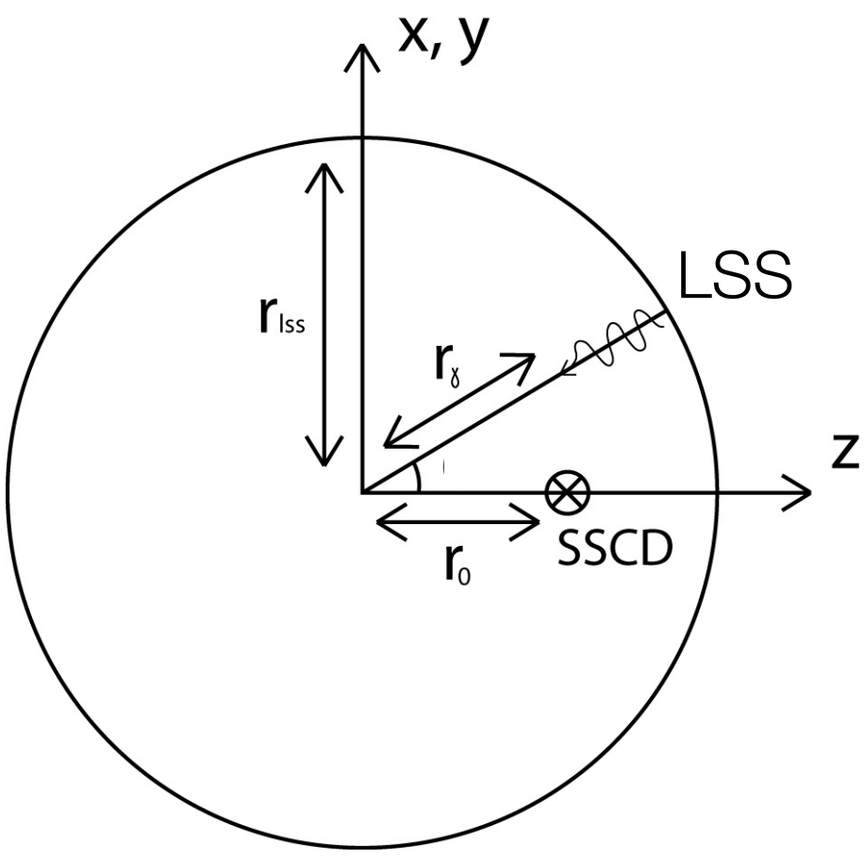

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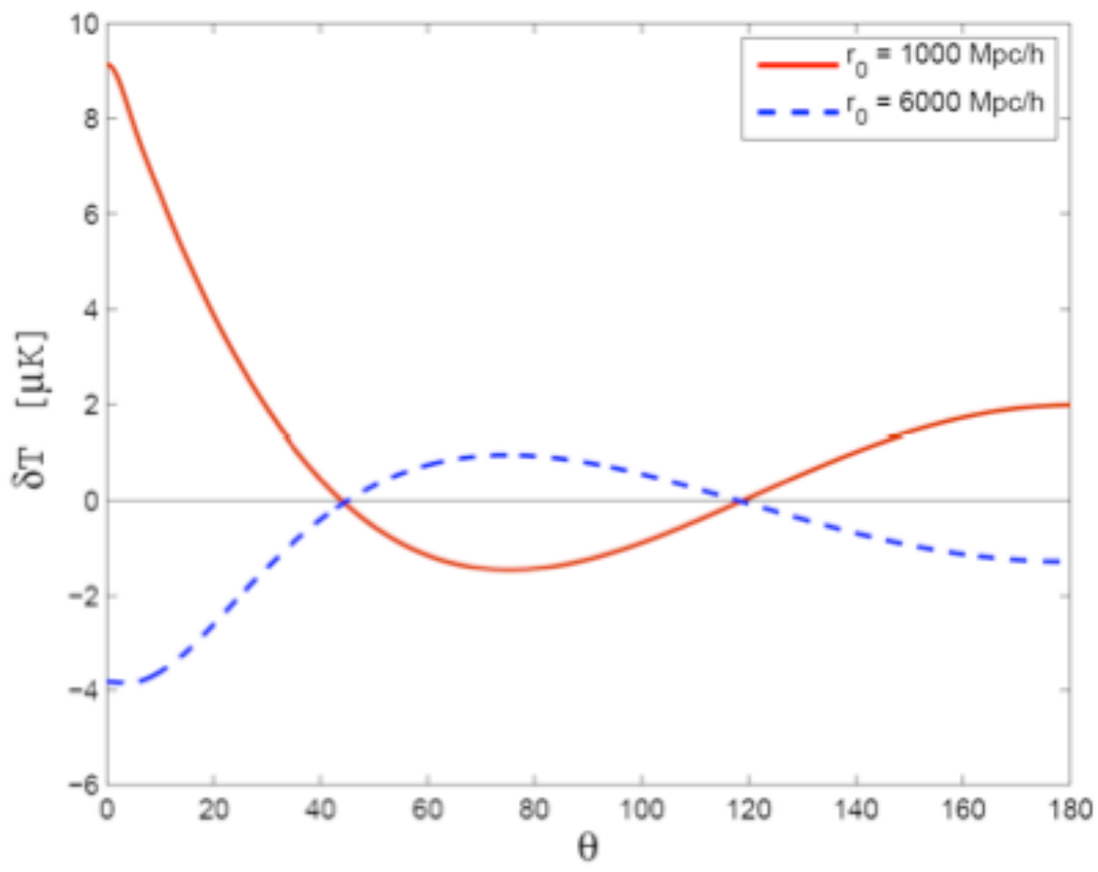
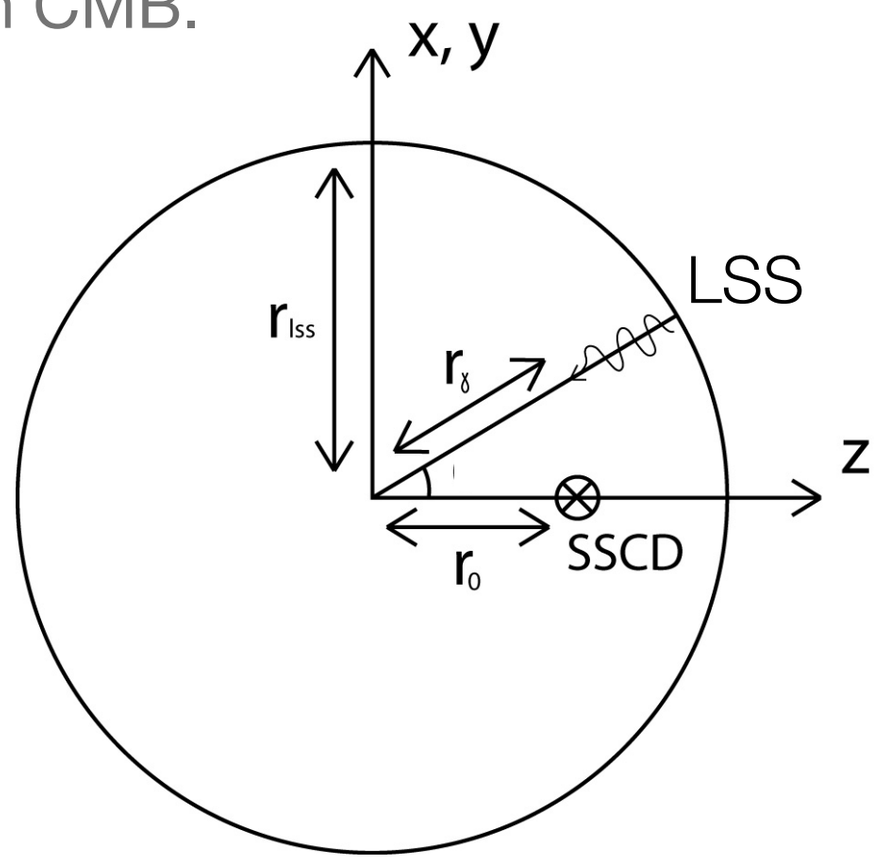
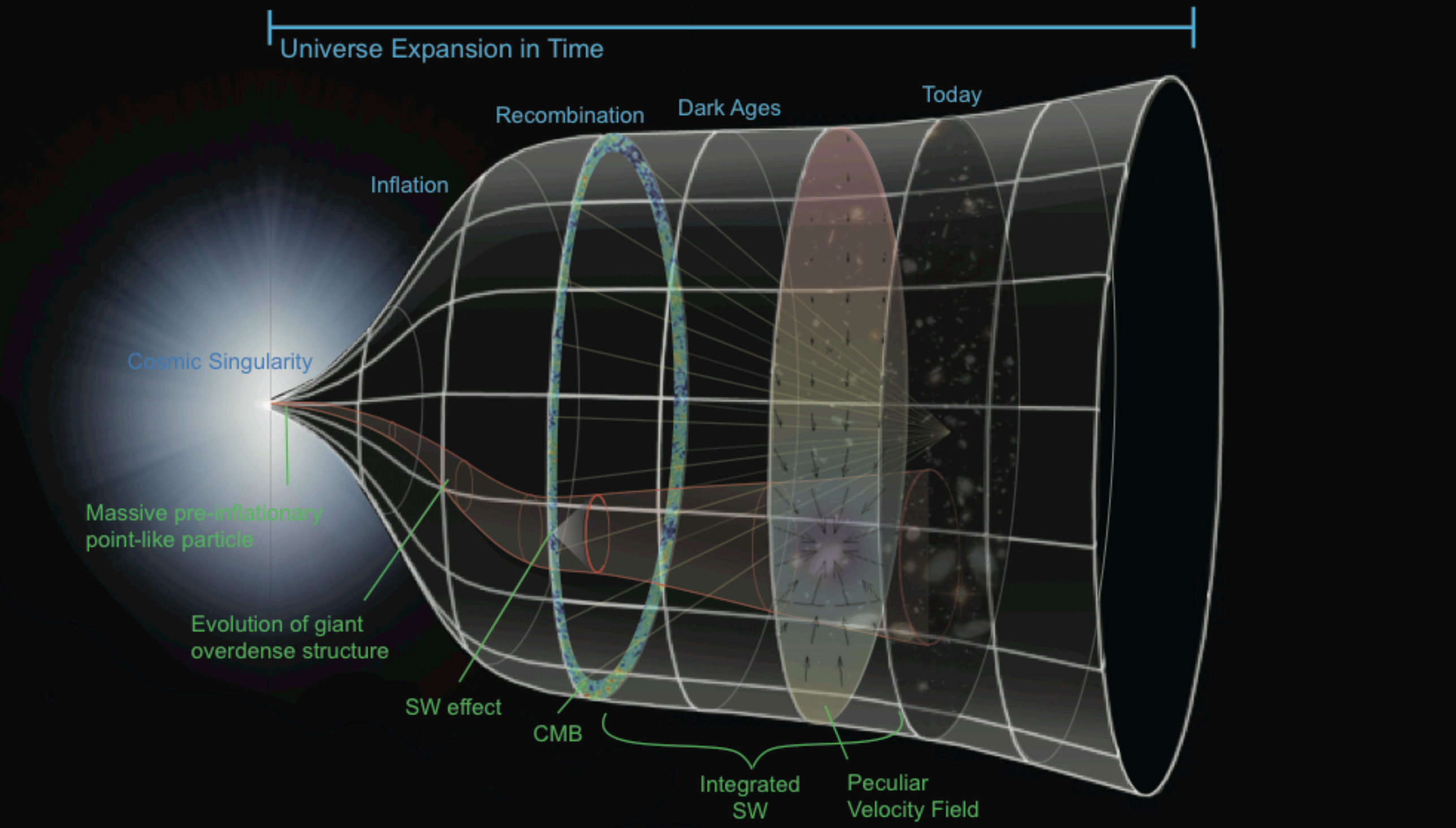
- Generic imprint: concentric hot and cold rings in CMB.





ΛCDM Universe + Pre-Inflationary Particle (PIP)



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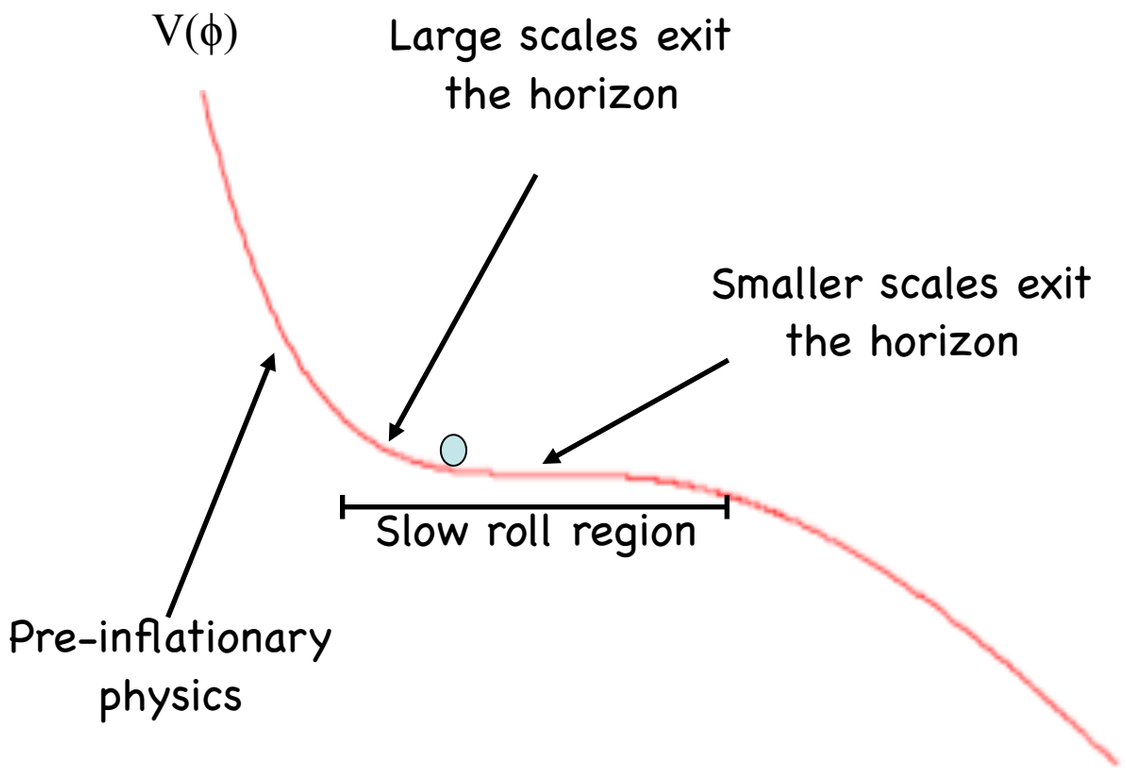

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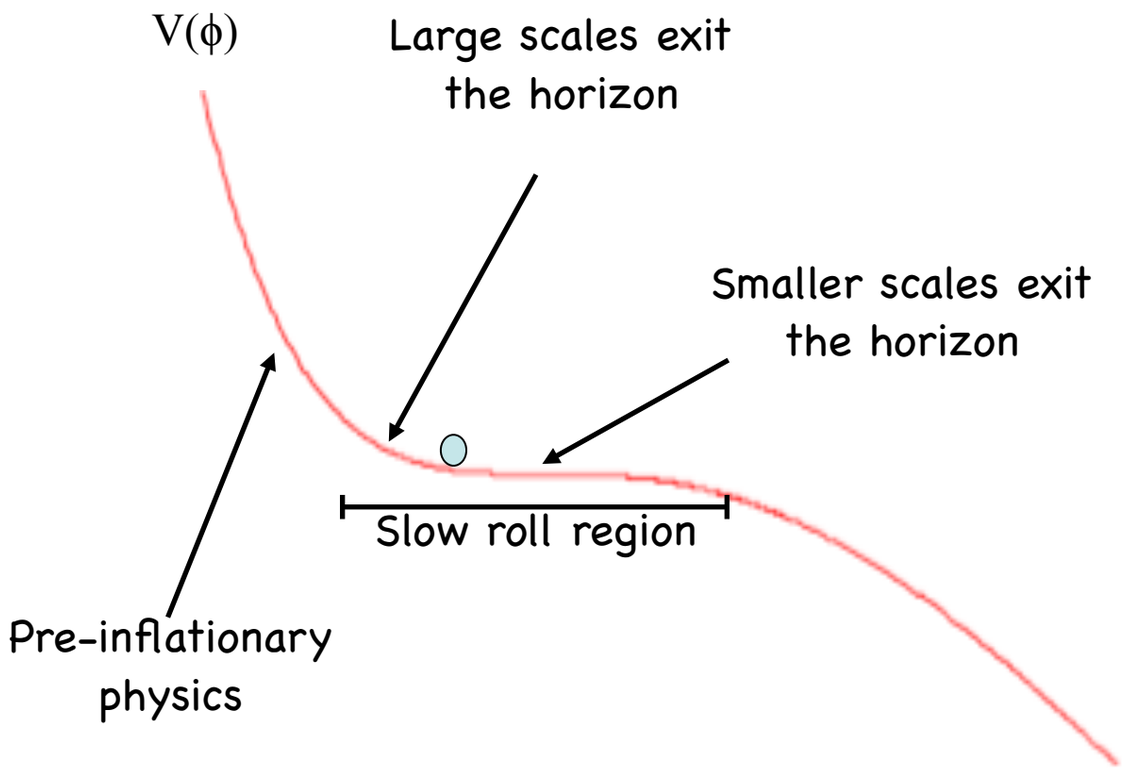

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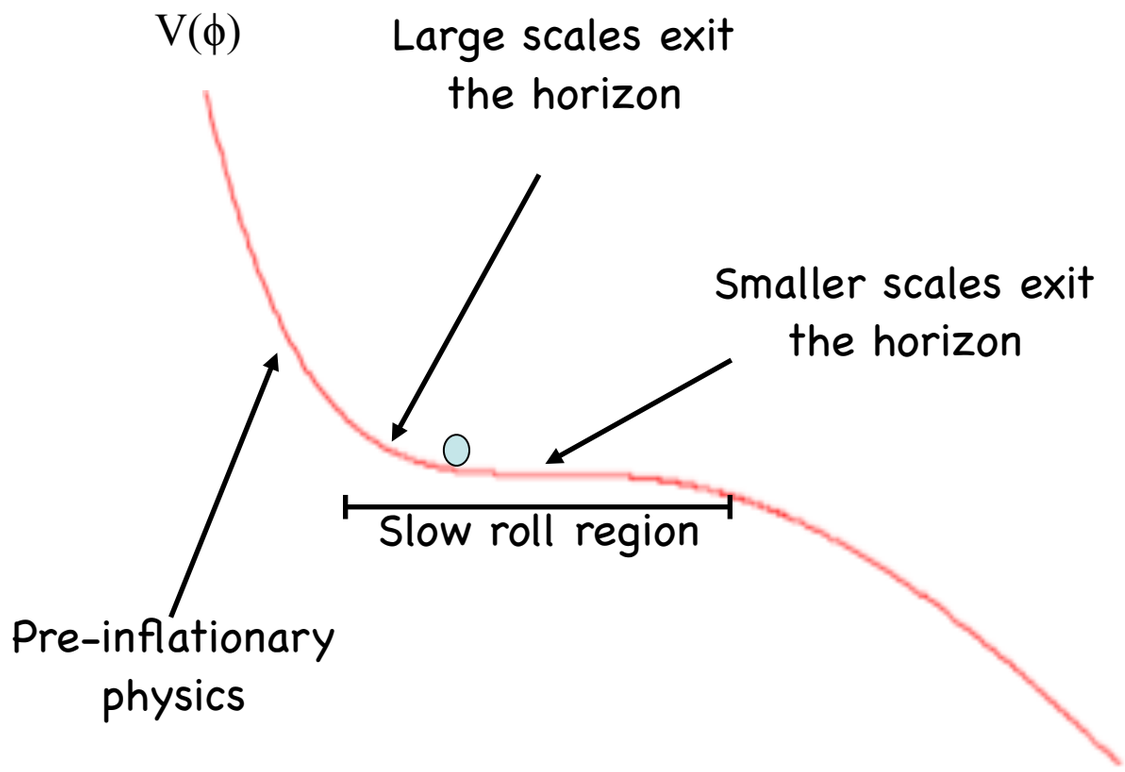

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- Logarithmic gravitational potential $\longrightarrow$ long-range effect.

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  - Test: CMB Giant Rings!

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- Overdense region with long-range gravitational potential:

▸ Test: Bulk flow (towards this “great attractor”)!

Rings Score - Definition

(EDK, Ben-David and Itzhaki, ApJ 2010)

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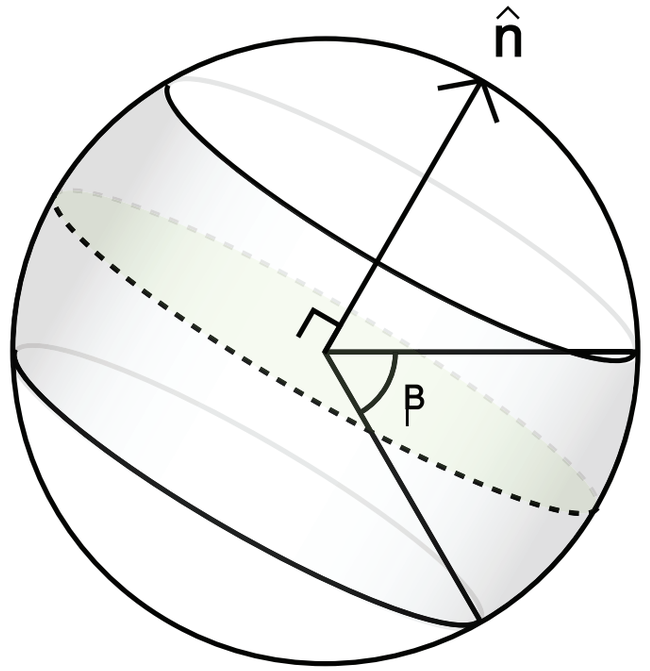

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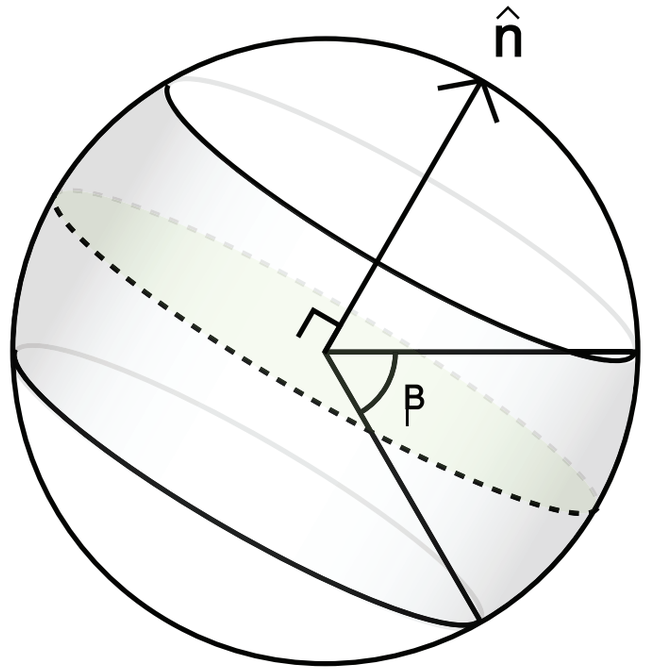

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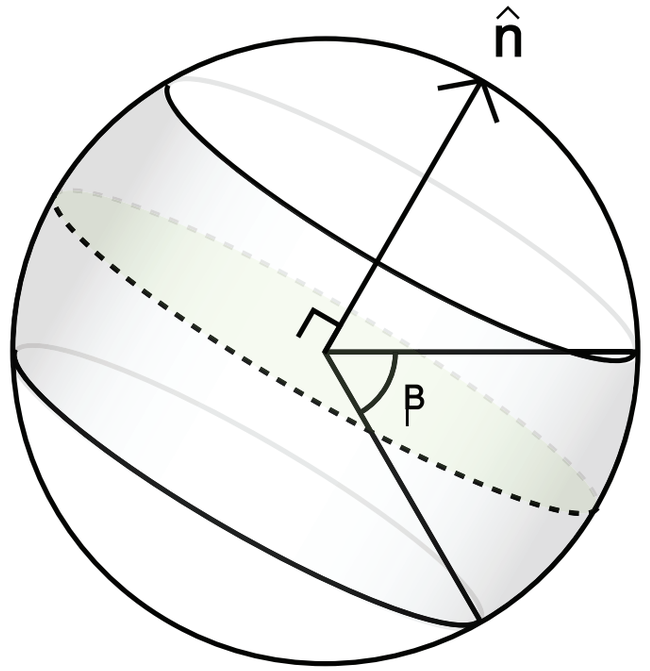

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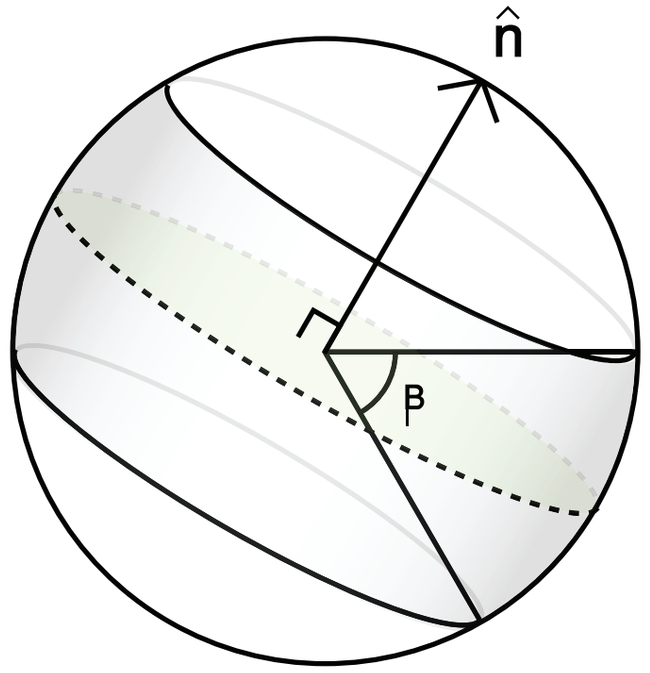

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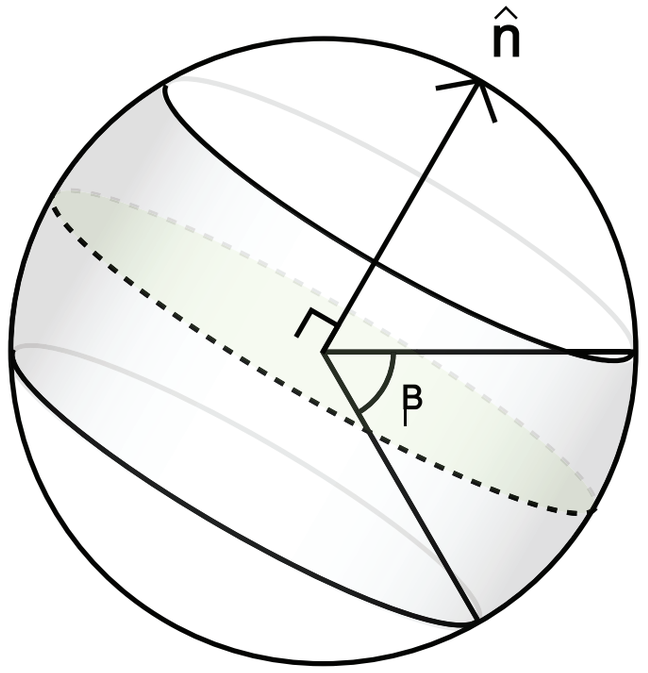

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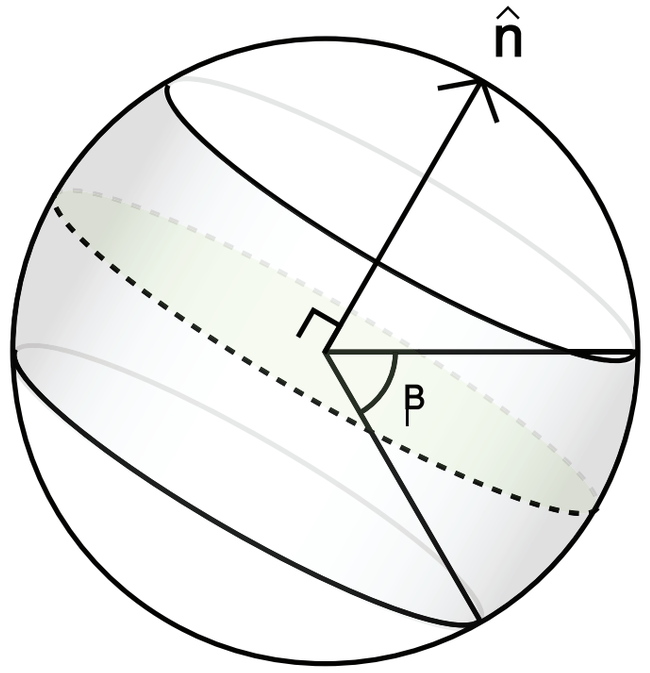
- T_0 = mean of the total map
- Calculate the following:

$$R(\beta, \hat{n}) = \int_{\frac{\pi-\beta}{2}}^{\frac{\pi+\beta}{2}} d(\cos\theta)\ \tilde{T}^2(\theta, \hat{n}),$$

$$\tilde{T}(\theta, \hat{n}) = T(\theta, \hat{n}) - T_0$$



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Our findings for WMAP7 ILC masked with KQ75:

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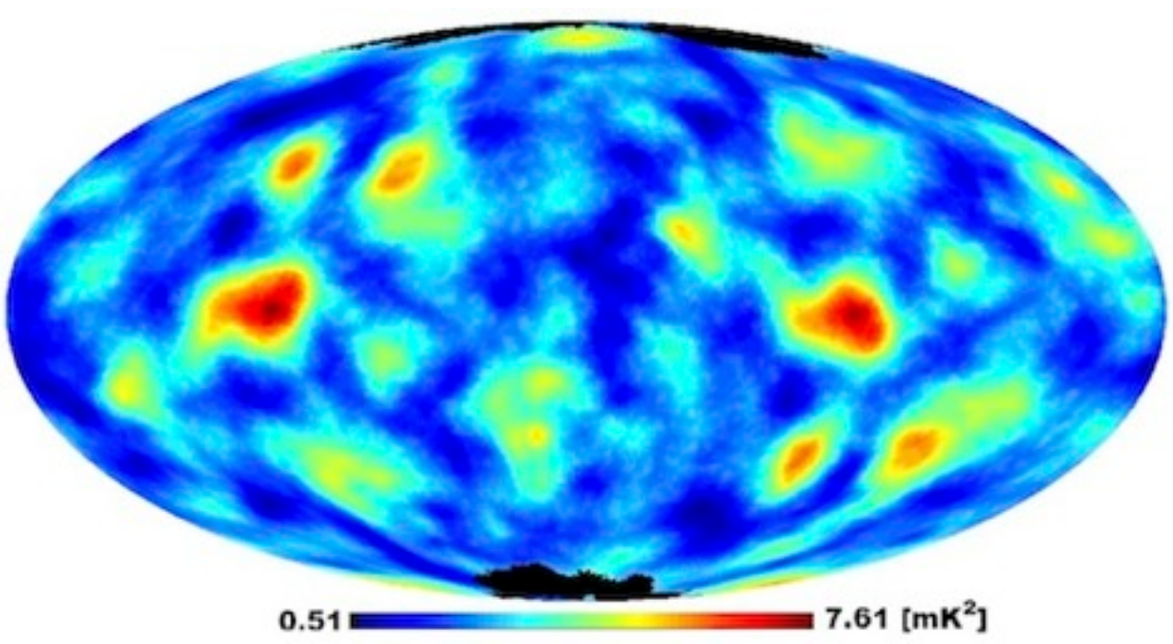

$$\beta = 90^\circ$$

Rings Score - Results

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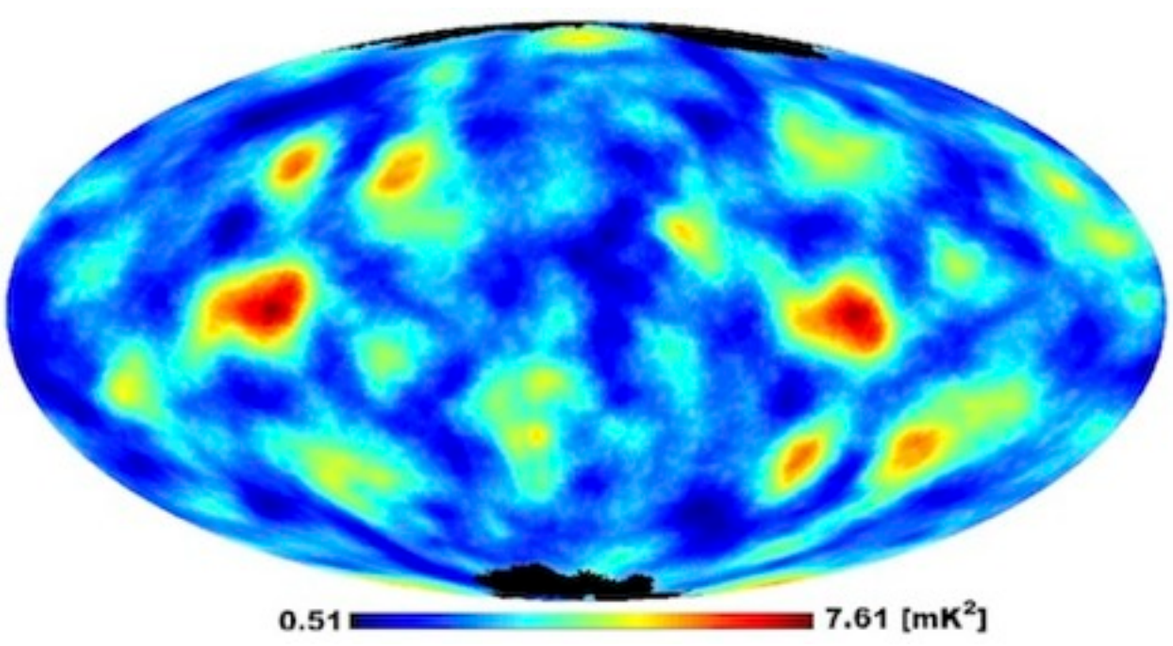
Our findings for WMAP7 ILC masked with KQ75:

- We see a peak at around $(l, b) = (276°, -1°)$.



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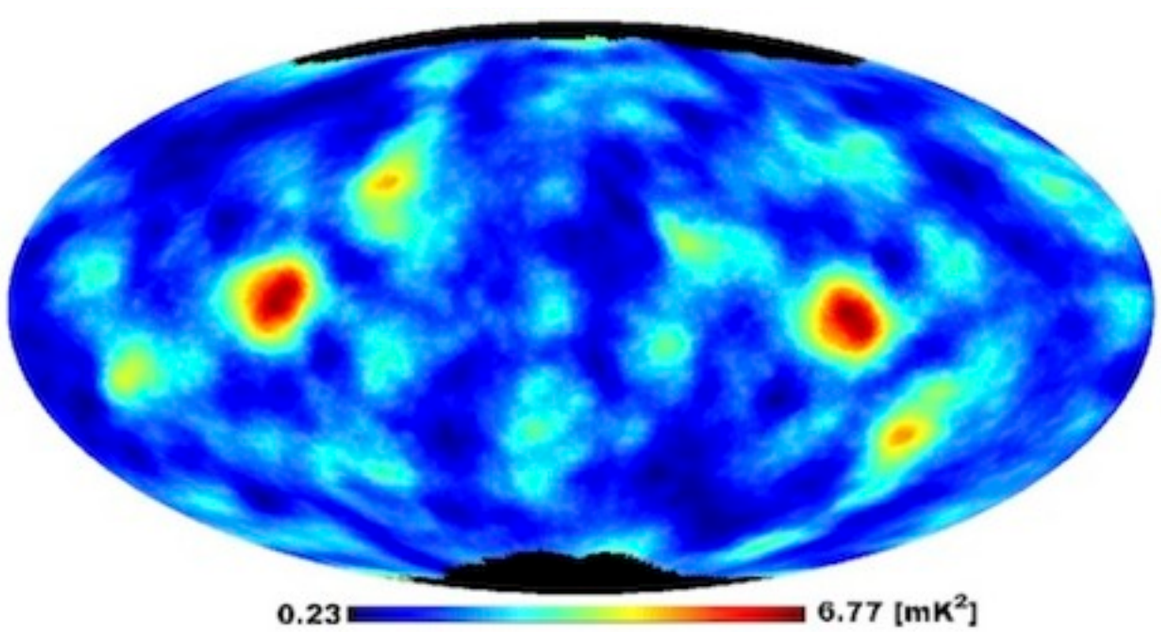

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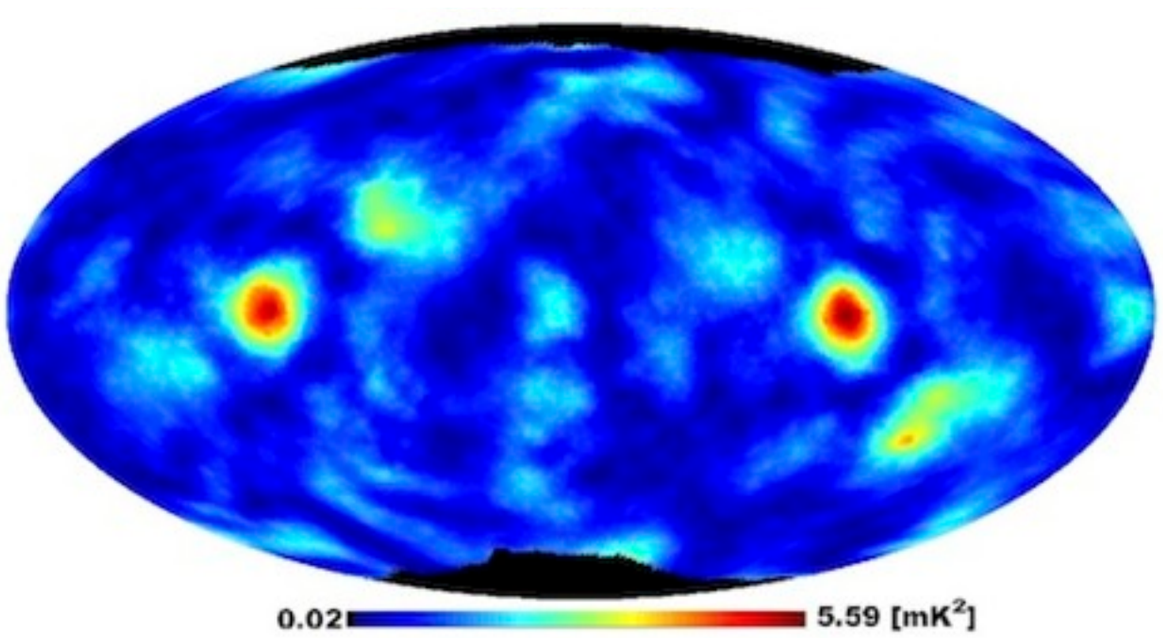

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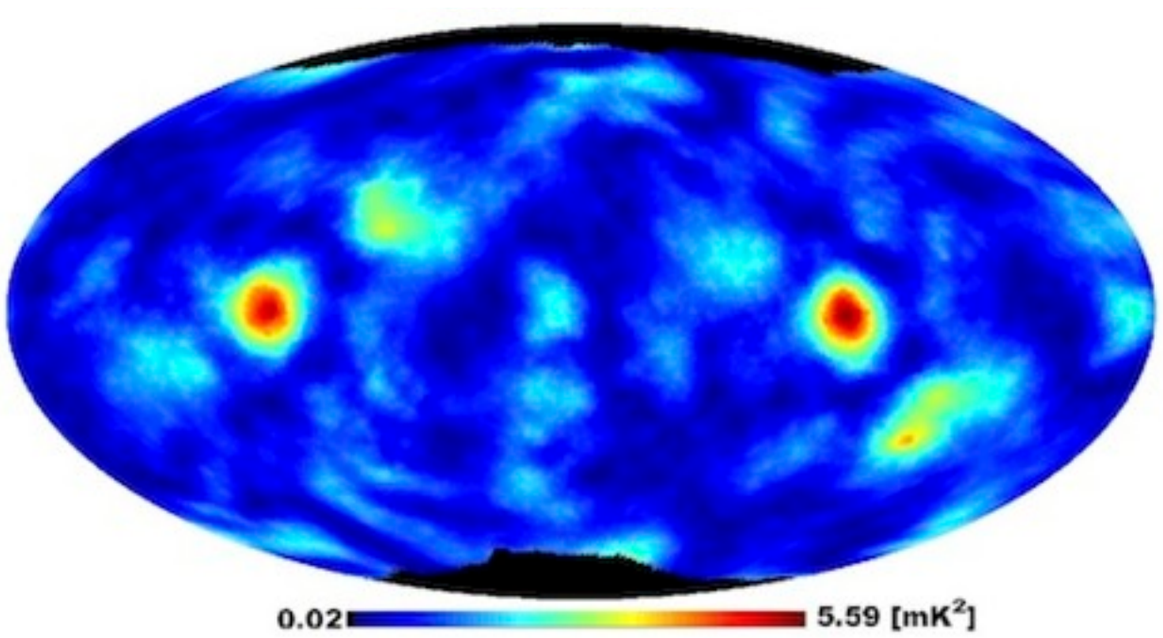

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Rings Score - Results

(EDK, Ben-David and Itzhaki, ApJ 2010)

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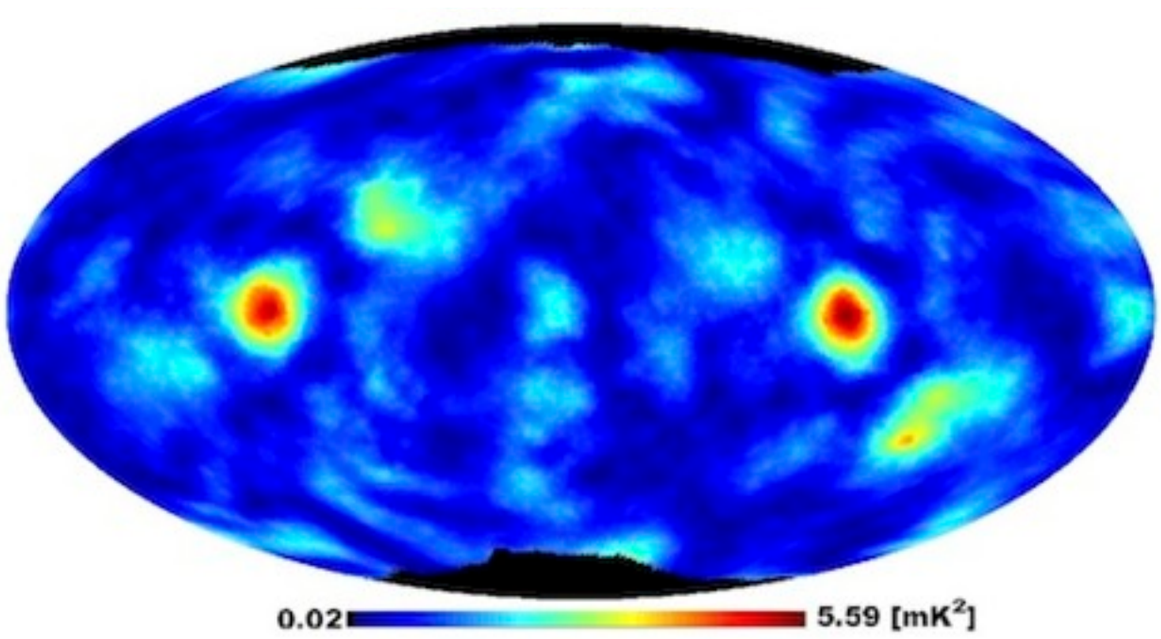

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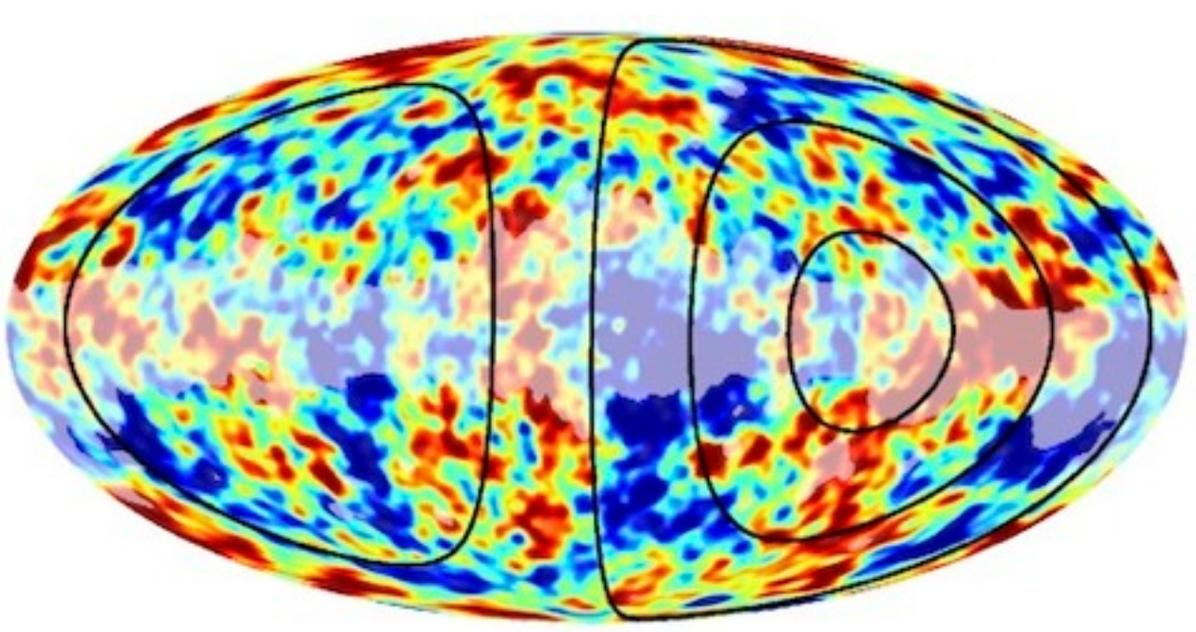

Rings in 7-year ILC map

Rings Score - COBE-DMR

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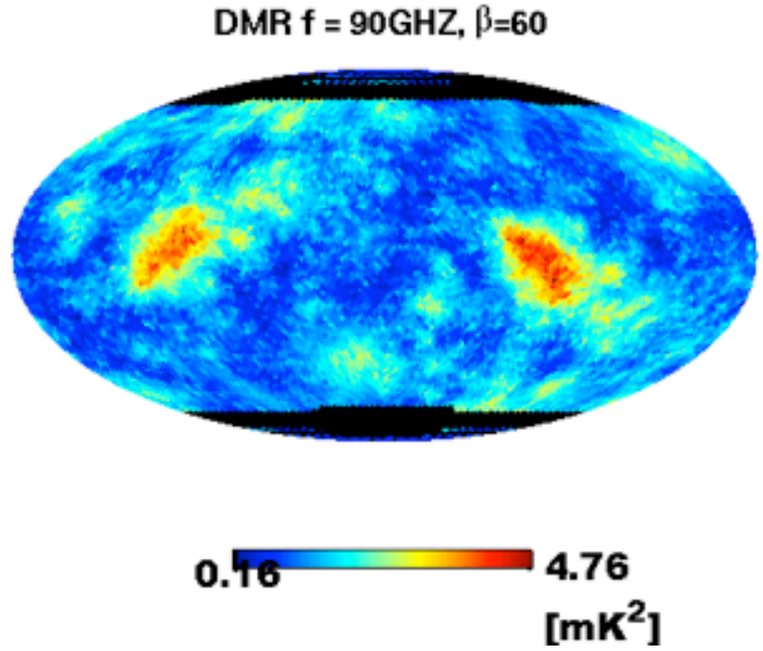
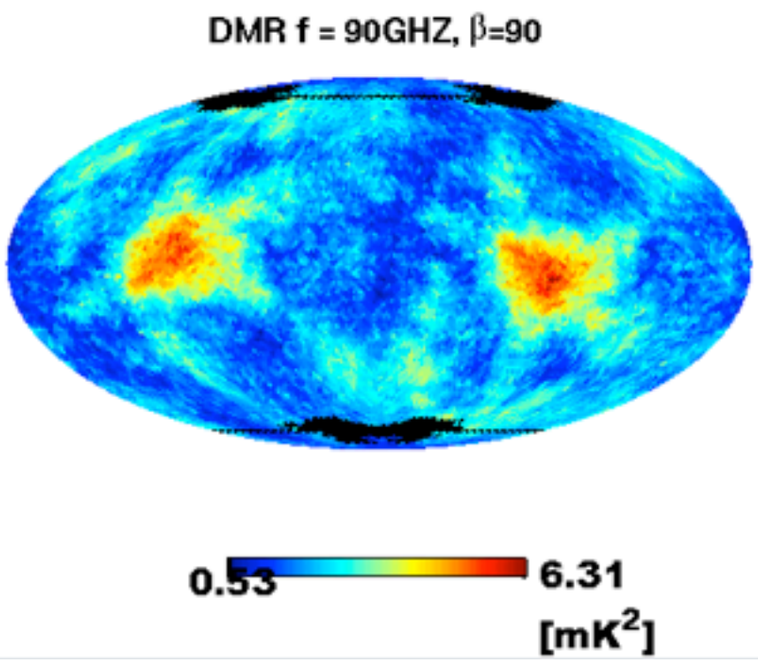
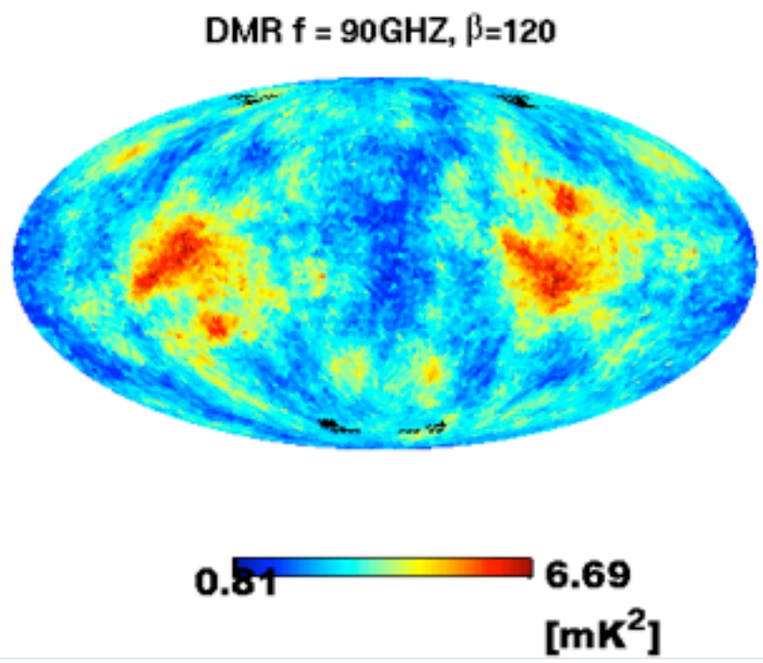
Low Resolution...







Bulk Flow - Direction

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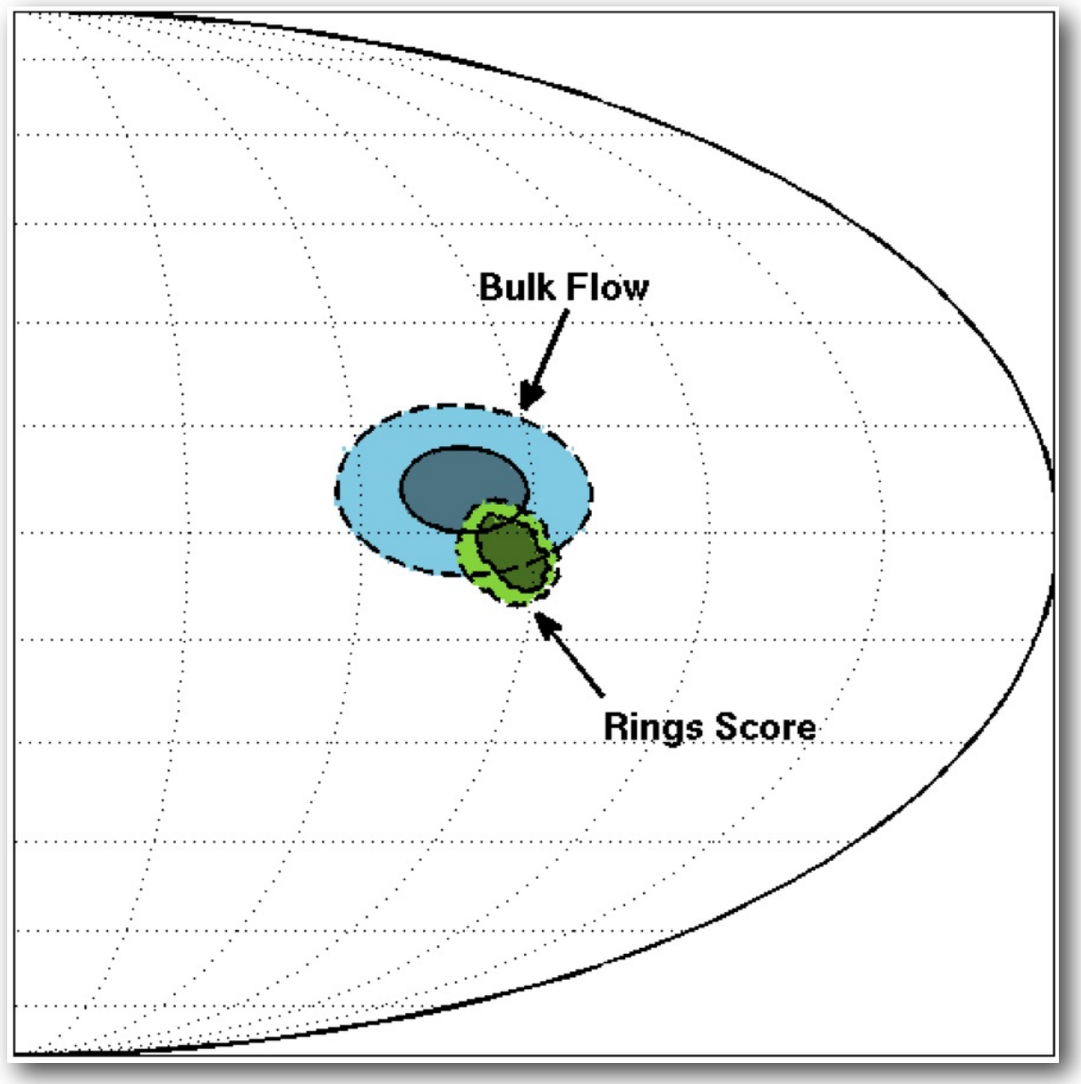

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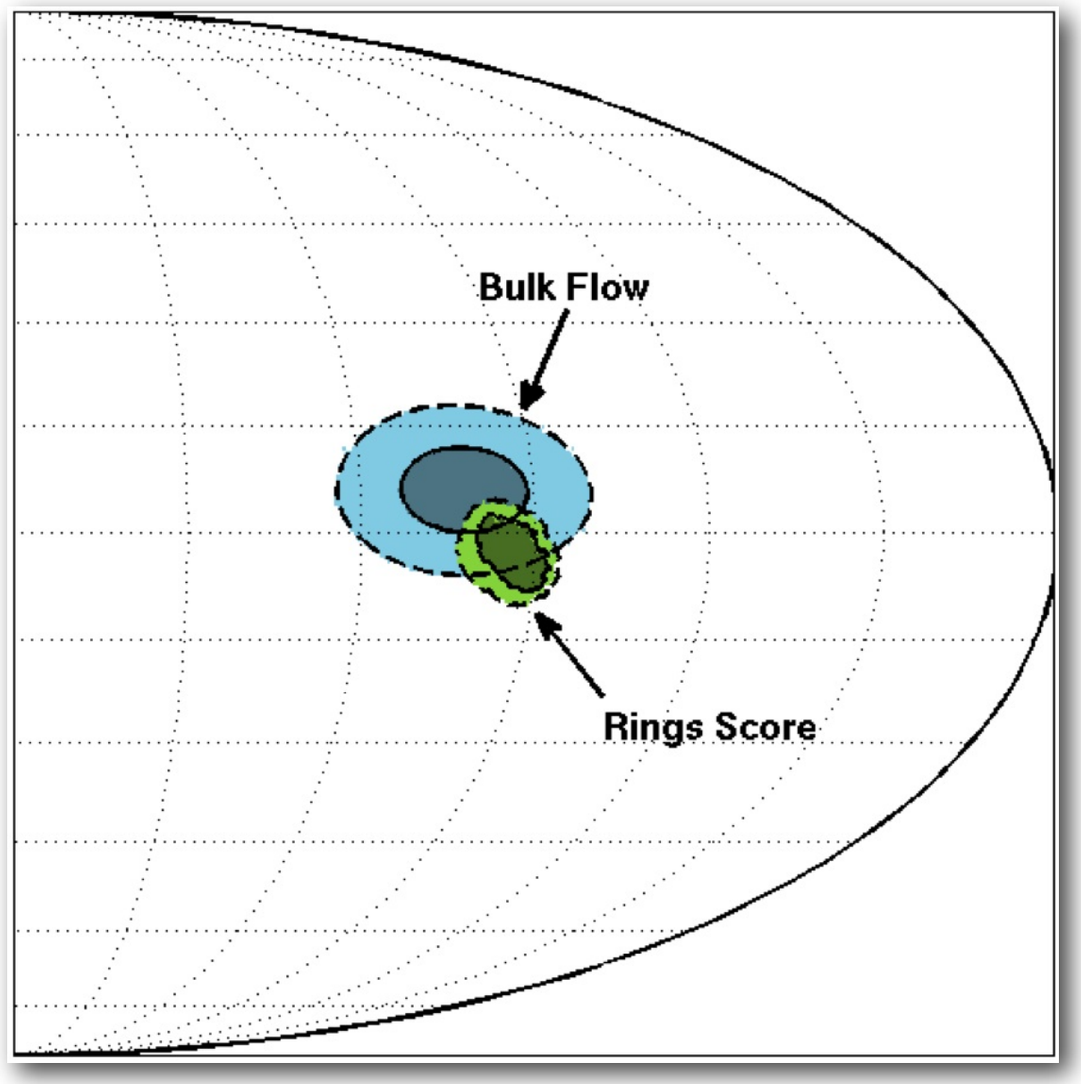
~1% chance alignment

with the center of the rings!



Parity - “S-Statistic”

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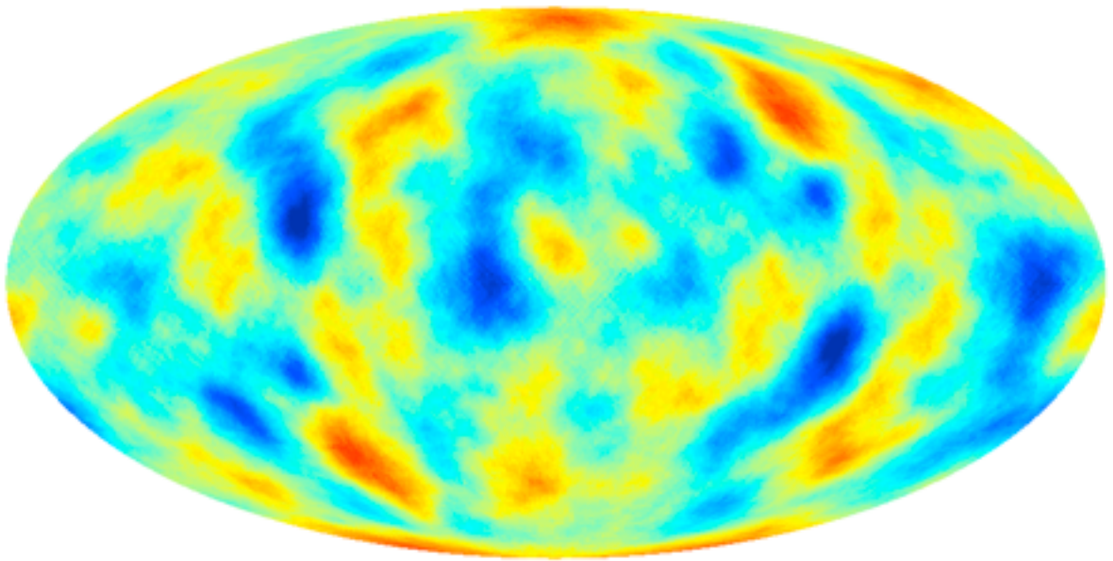

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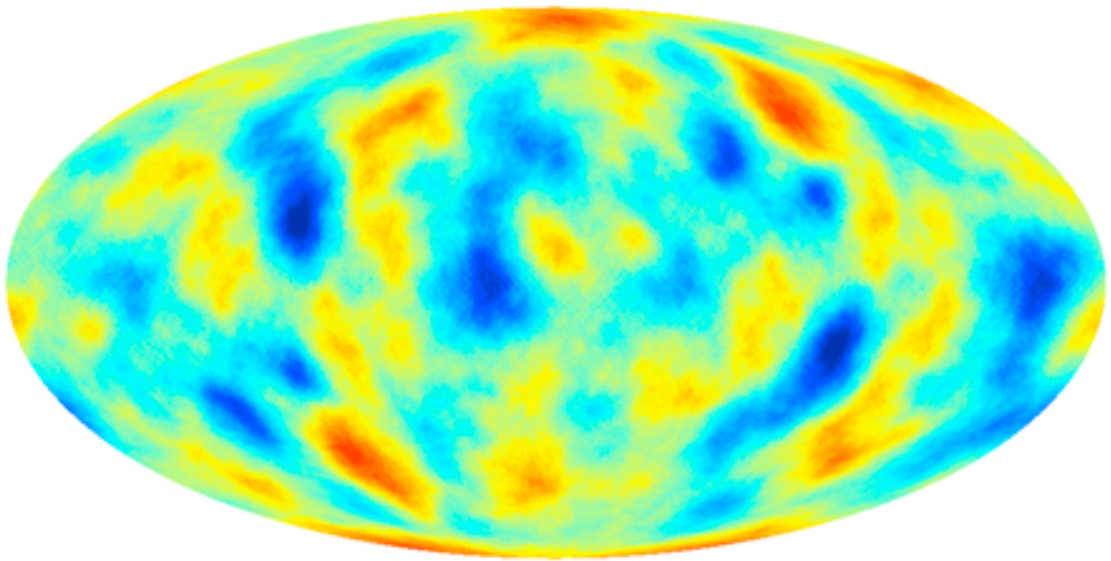

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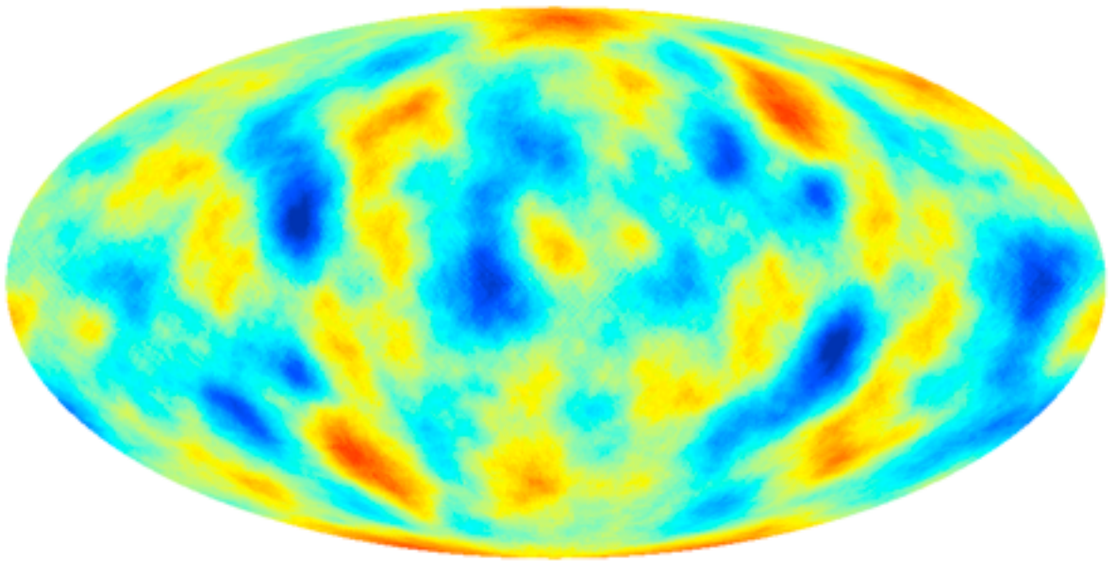

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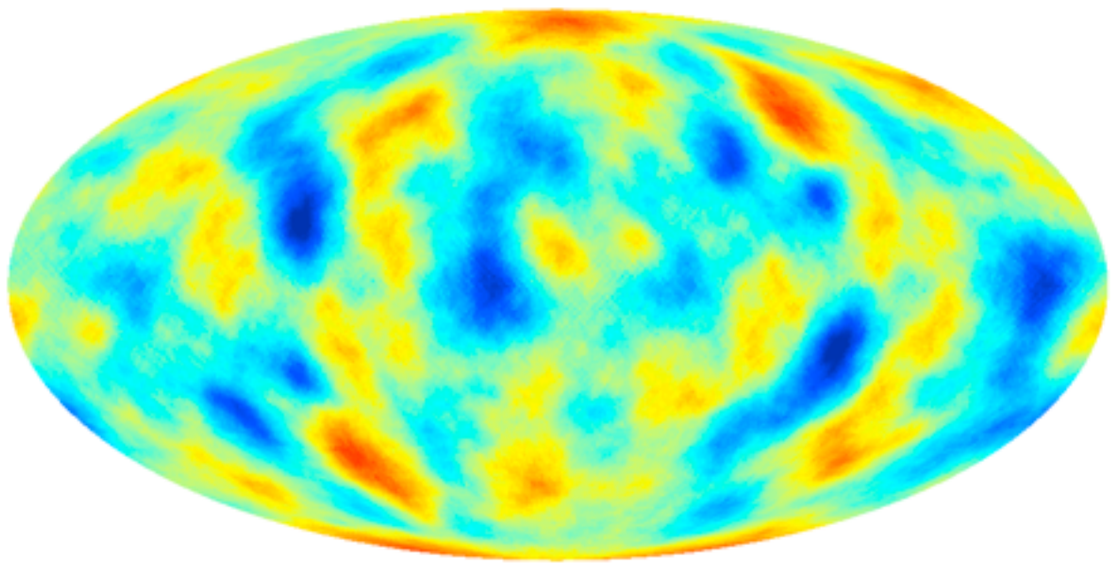

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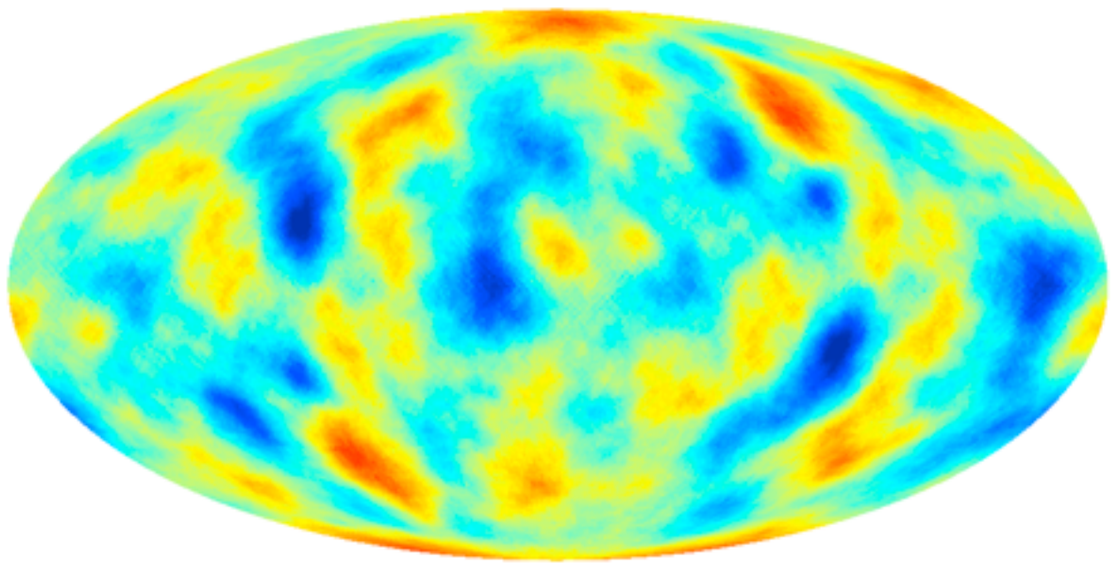

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Parity - Even/Odd Multipoles

(Ben-David, EDK and Itzhaki, ApJ 2012)

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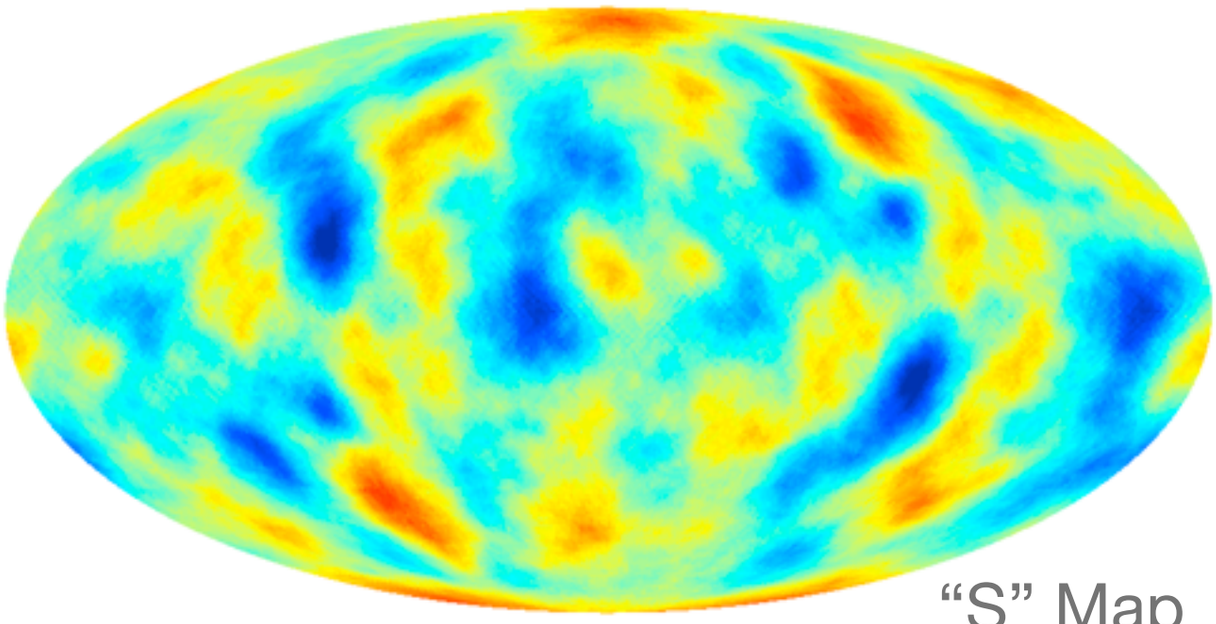

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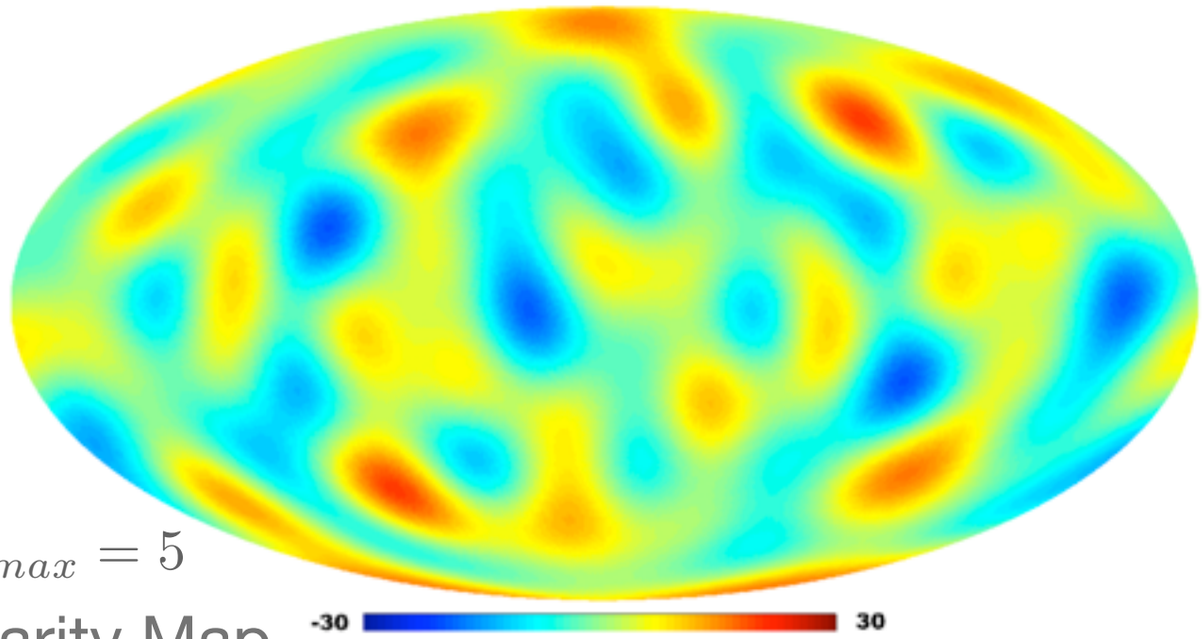

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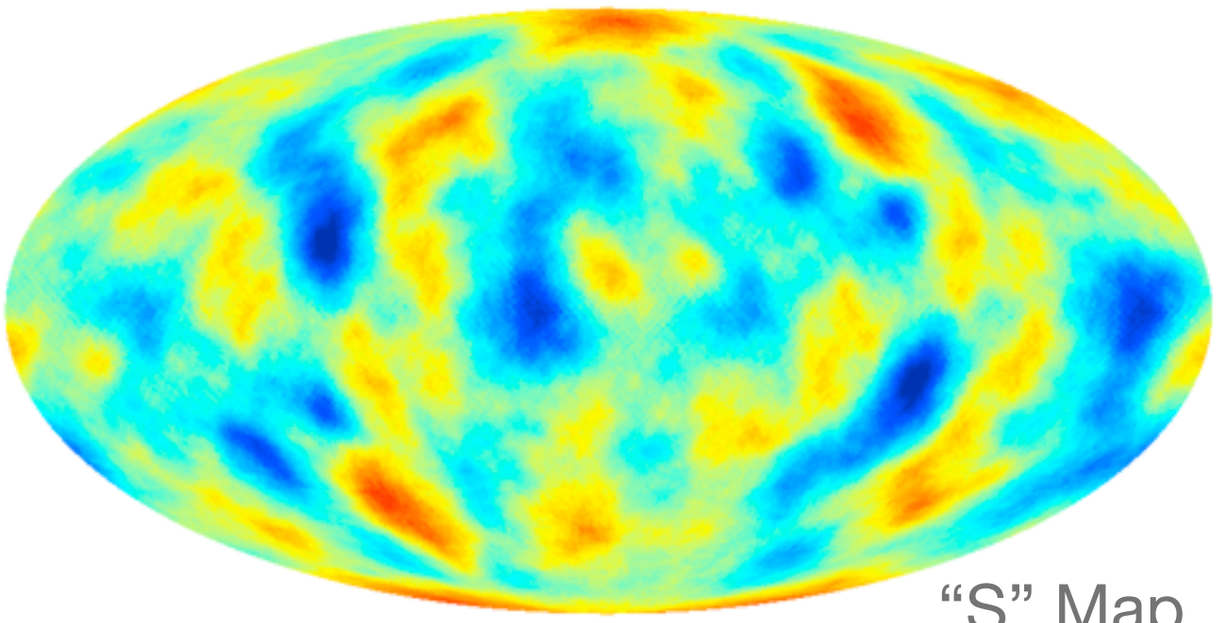
Parity Map



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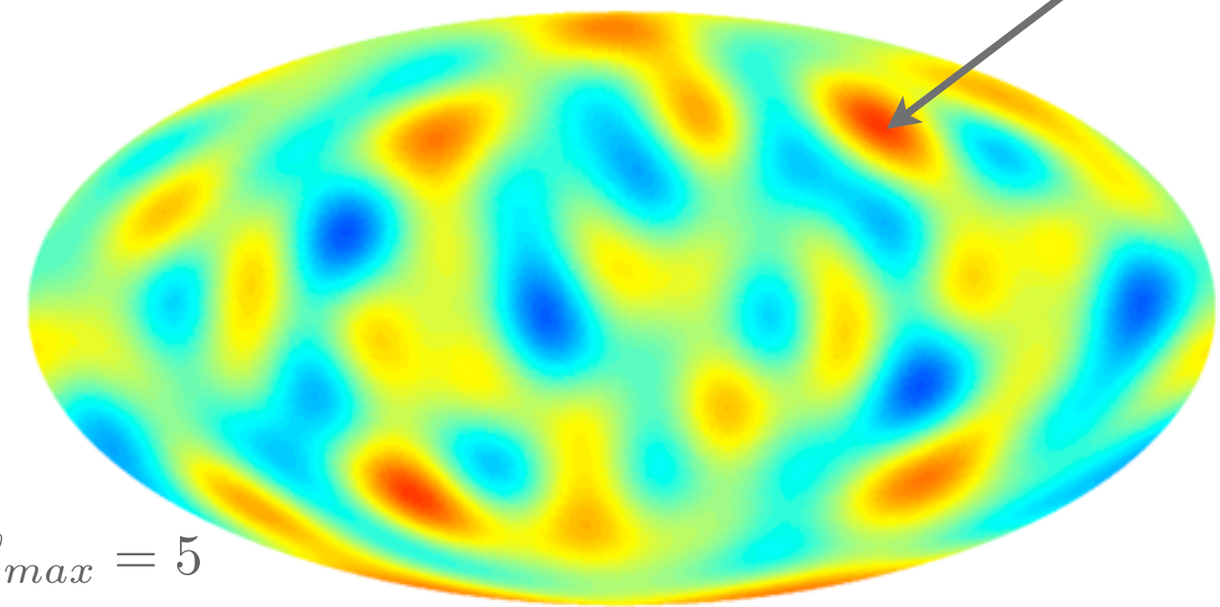

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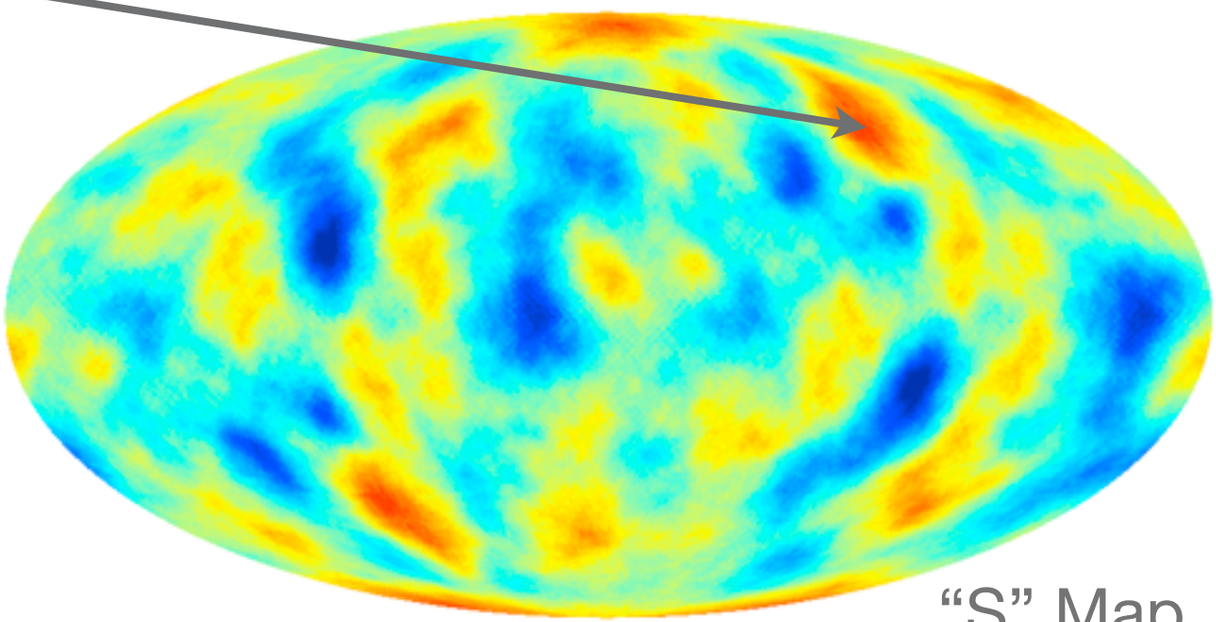

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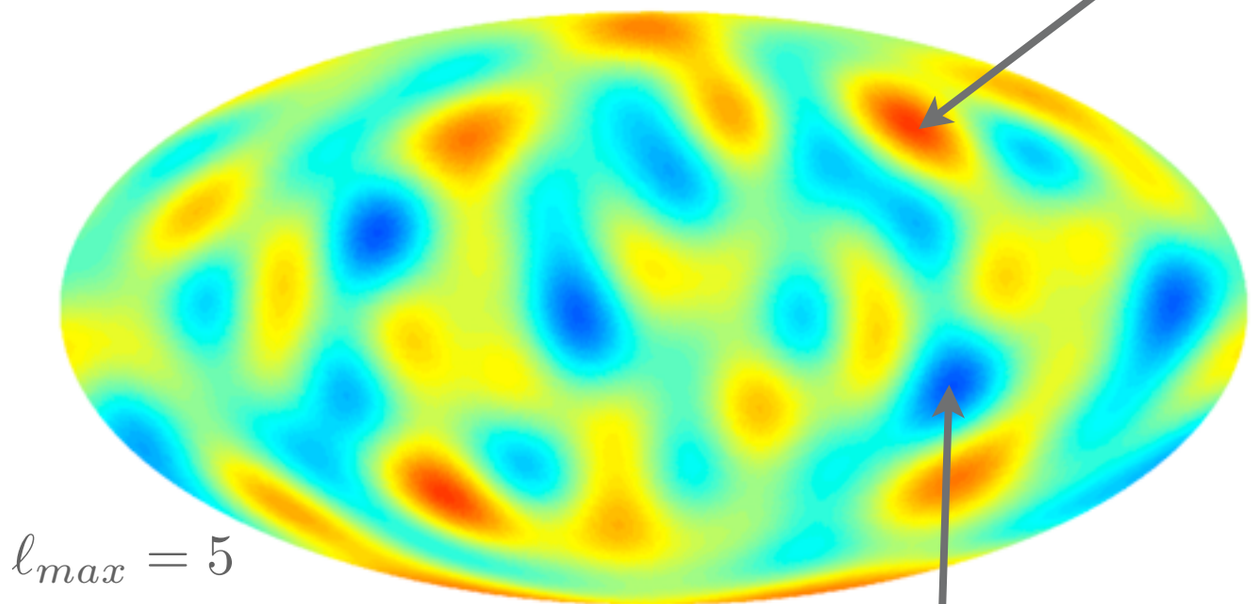

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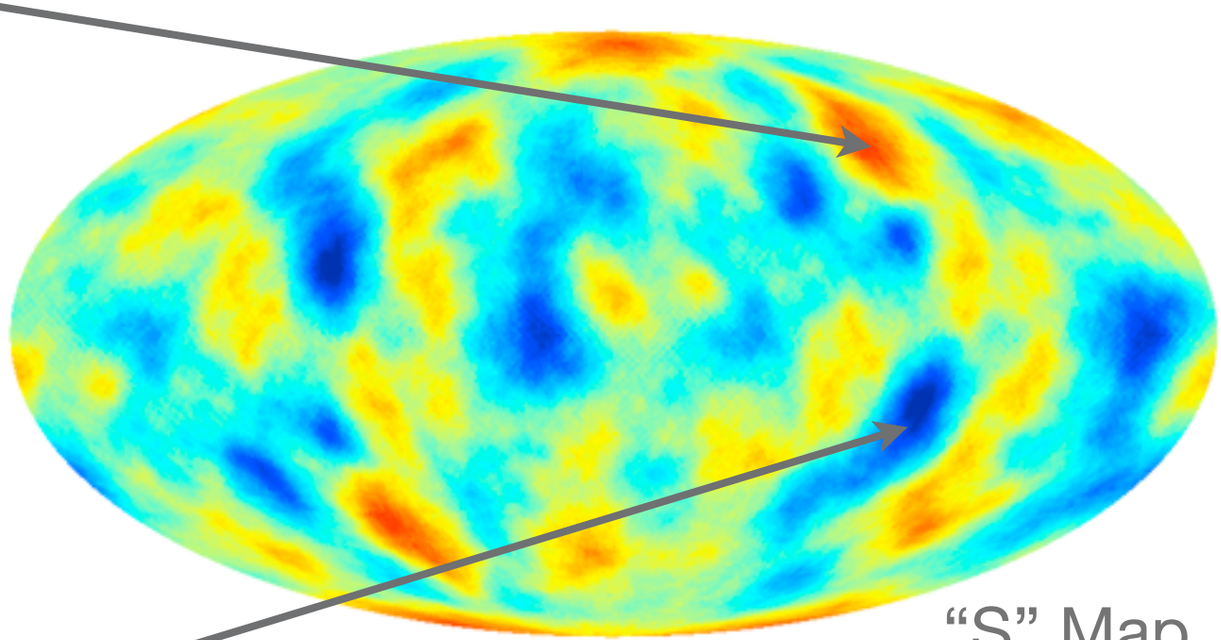

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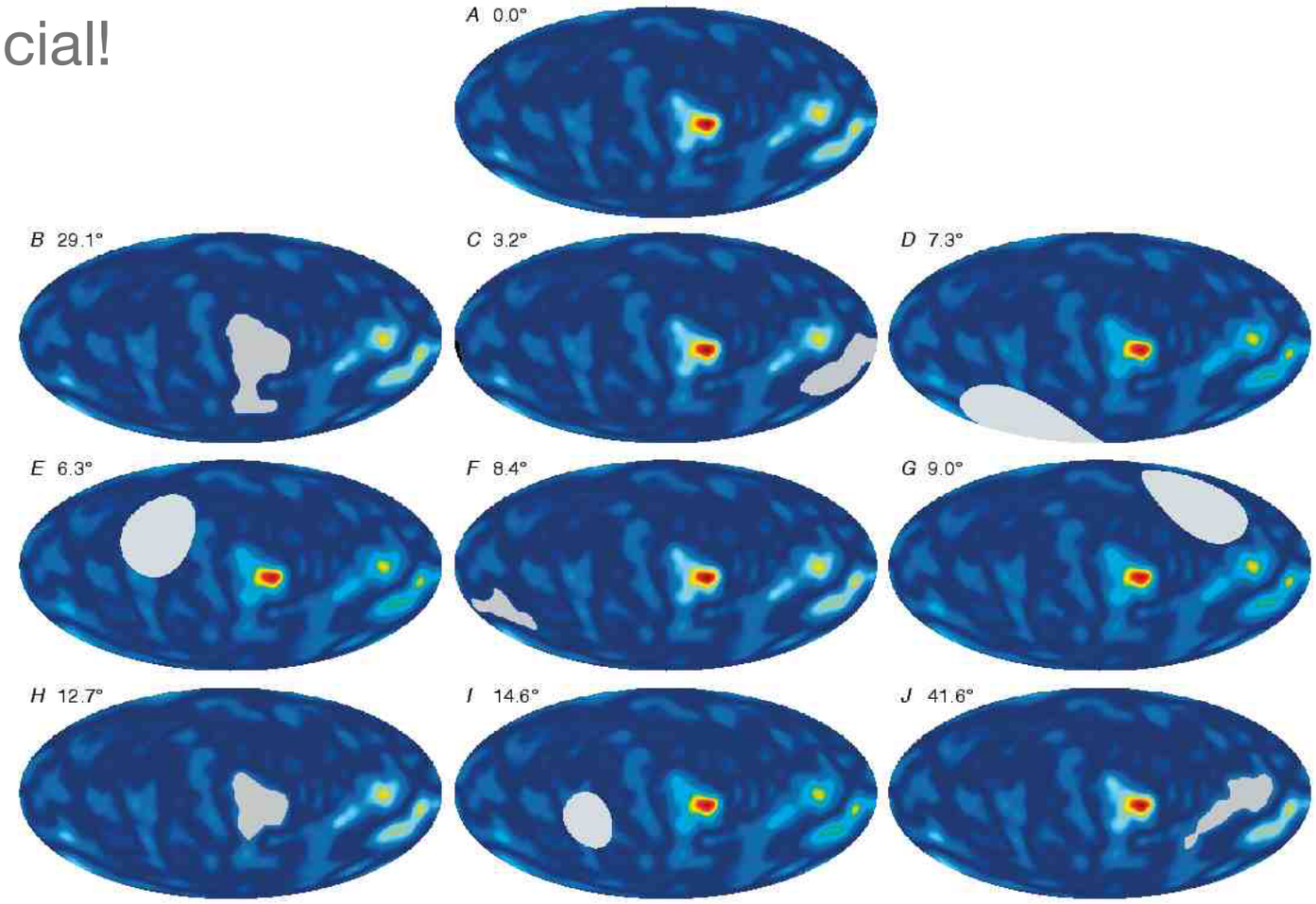

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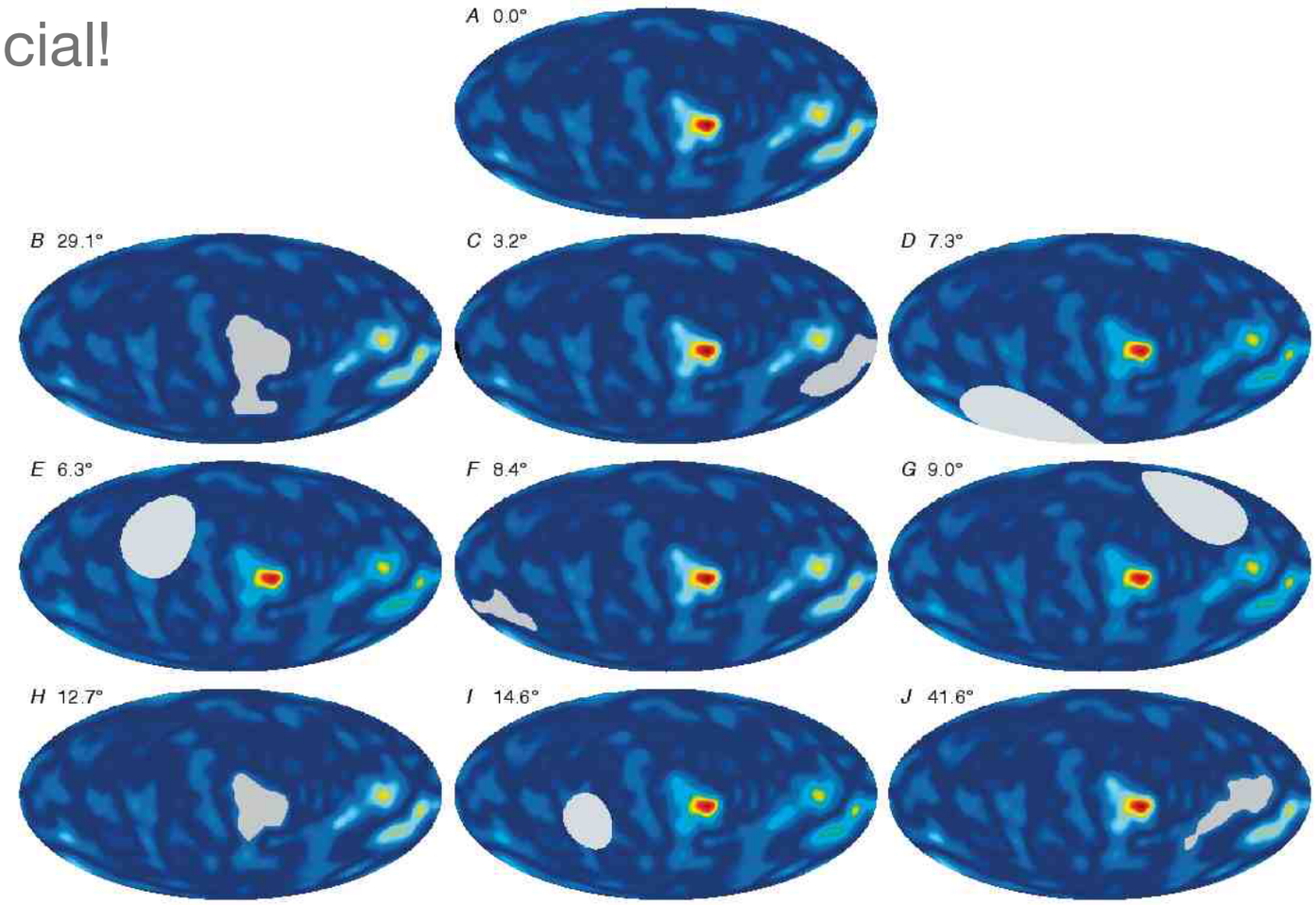

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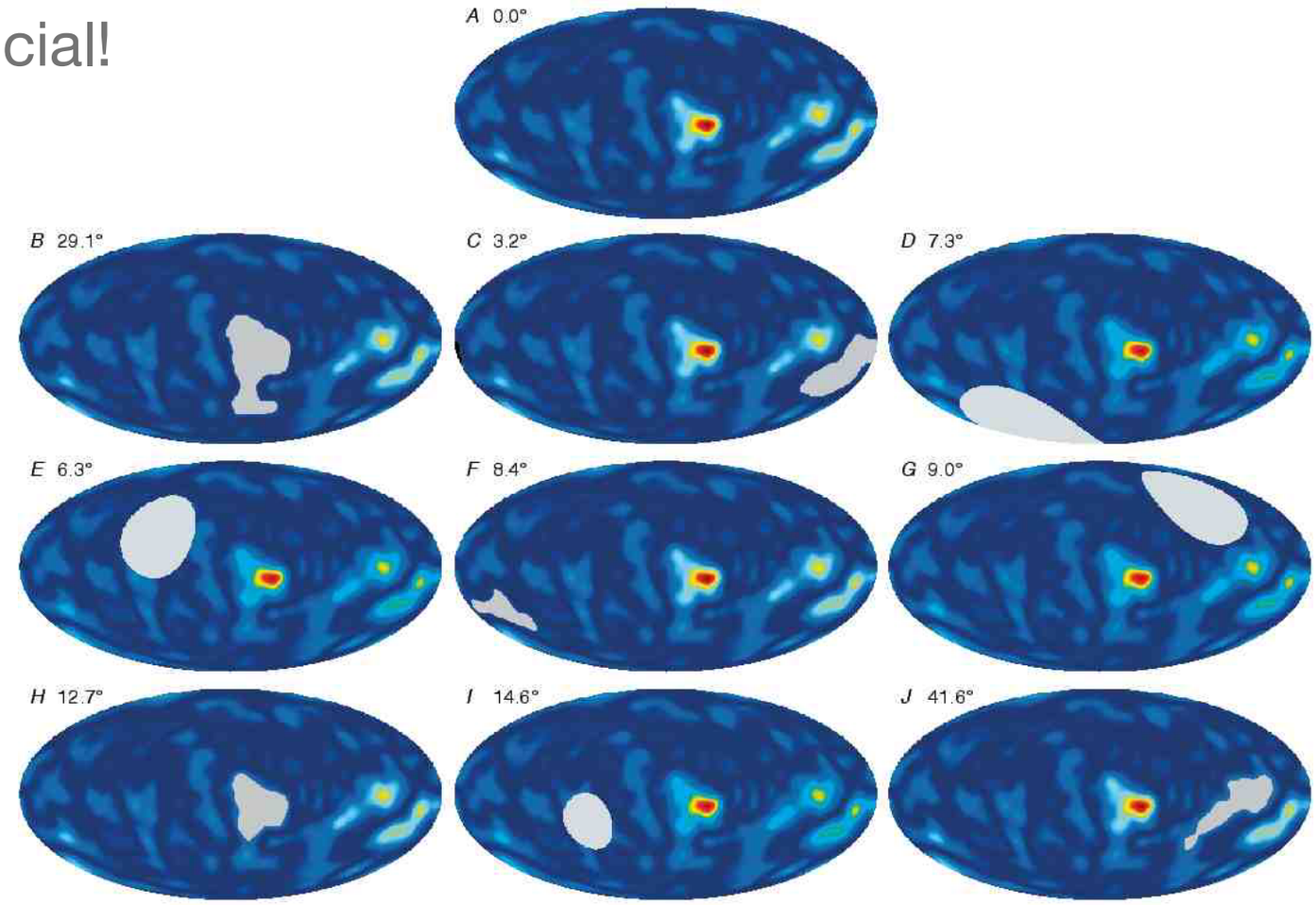

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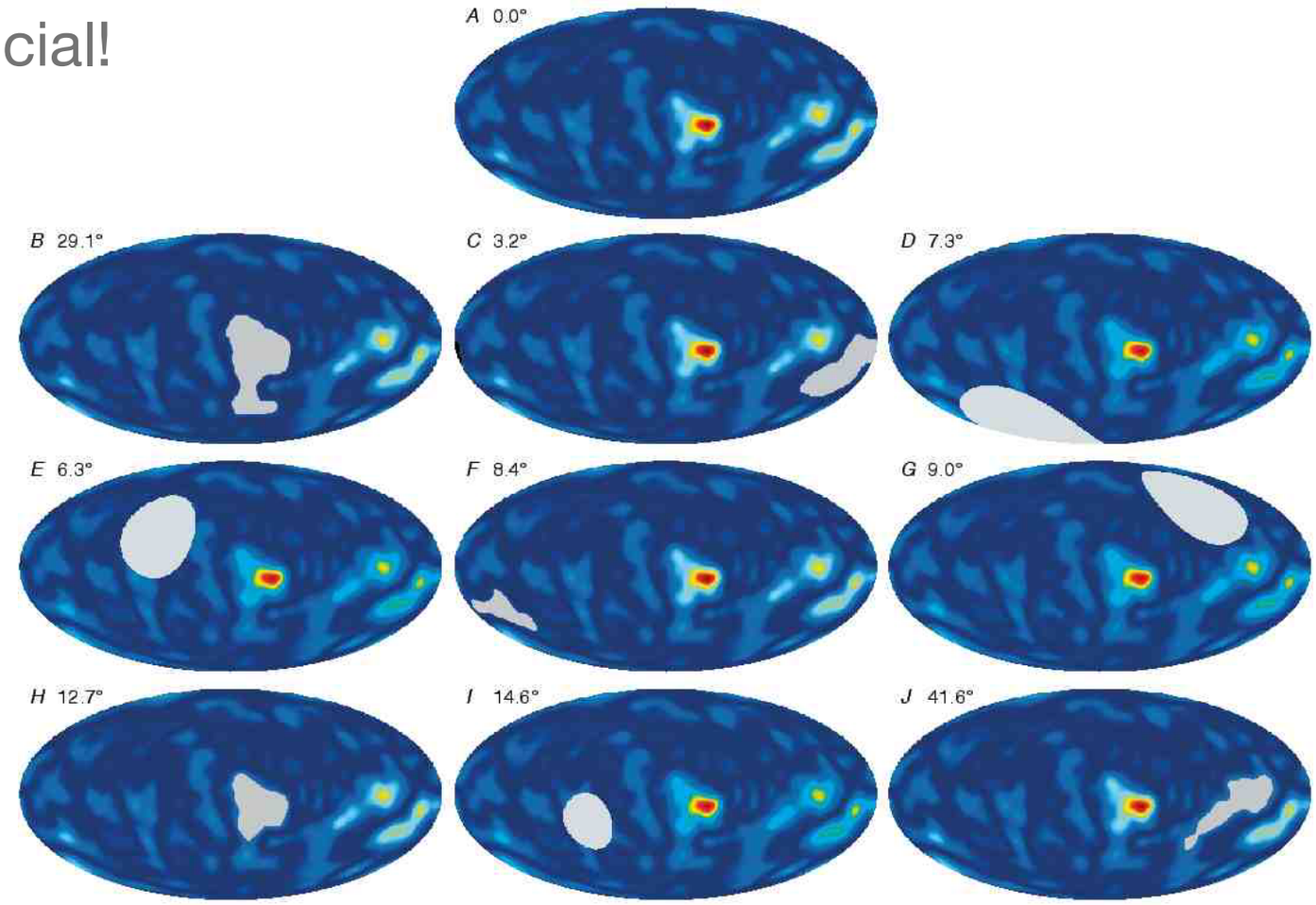

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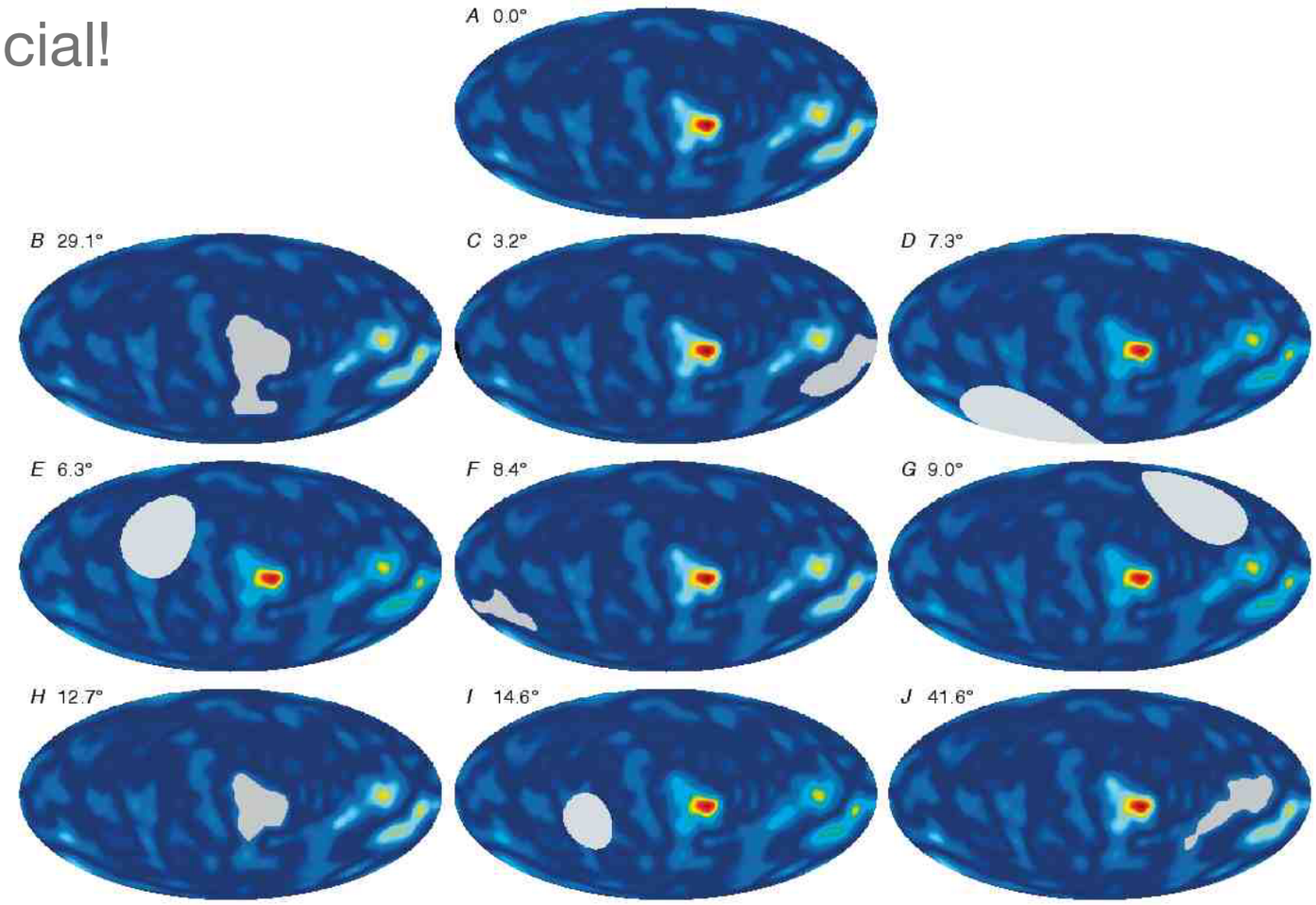

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Parity - Cut-Sky Results

(Ben-David, EDK and Itzhaki, ApJ 2012)

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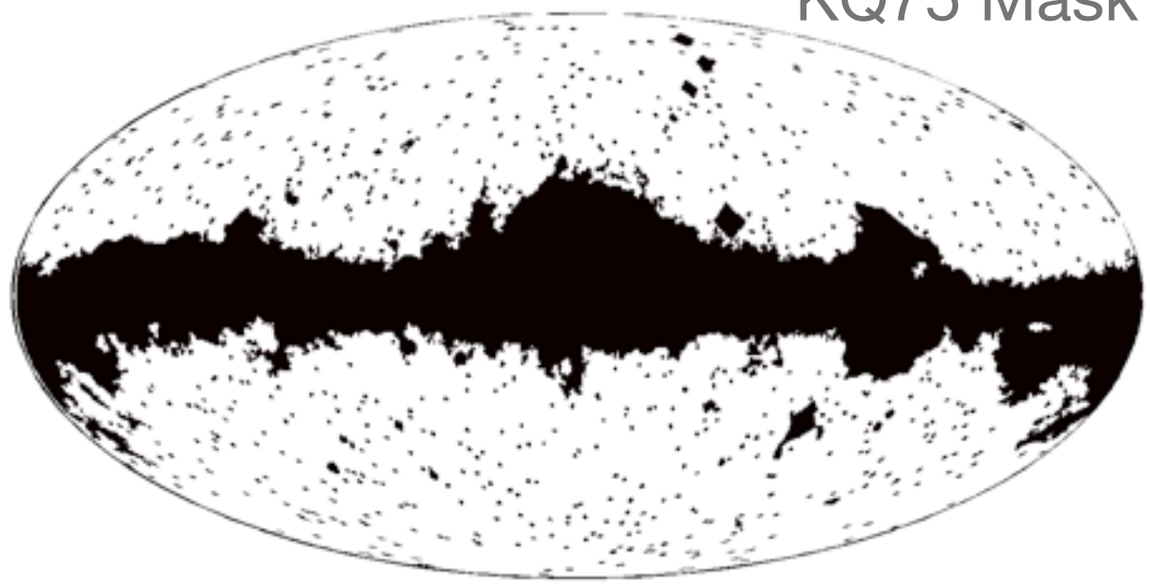
Aspen Winter 2012

Parity - Cut-Sky Results

(Ben-David, EDK and Itzhaki, ApJ 2012)

Ely D. Kovetz
Aspen Winter 2012

KQ75 Mask



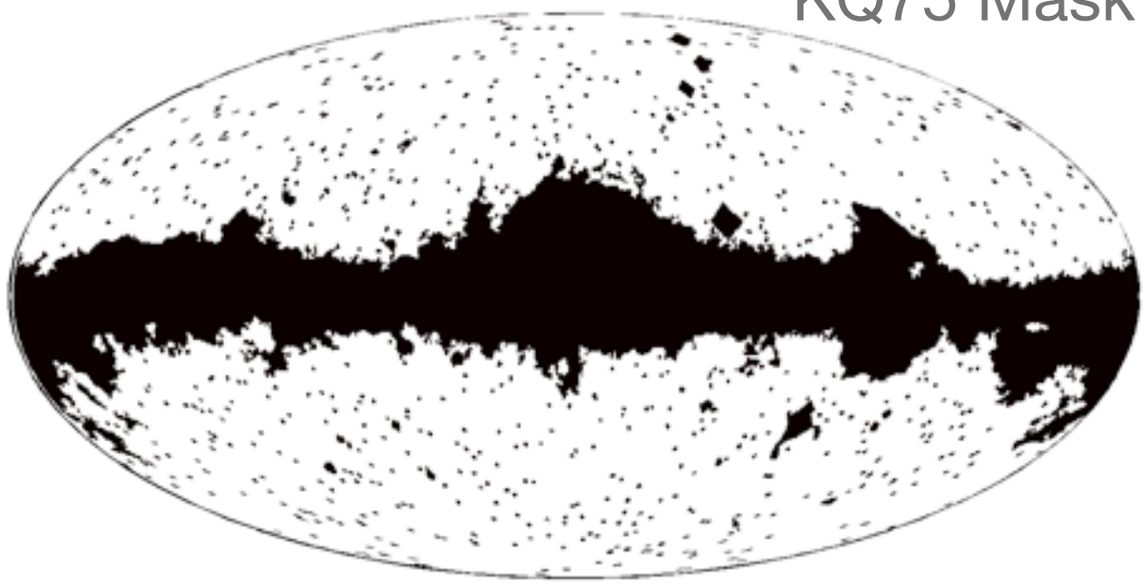
Parity - Cut-Sky Results

(Ben-David, EDK and Itzhaki, ApJ 2012)

Ely D. Kovetz
Aspen Winter 2012

- Mask out 2.5%-10% outlying pixels:

KQ75 Mask



Parity - Cut-Sky Results

(Ben-David, EDK and Itzhaki, ApJ 2012)

Ely D. Kovetz
Aspen Winter 2012

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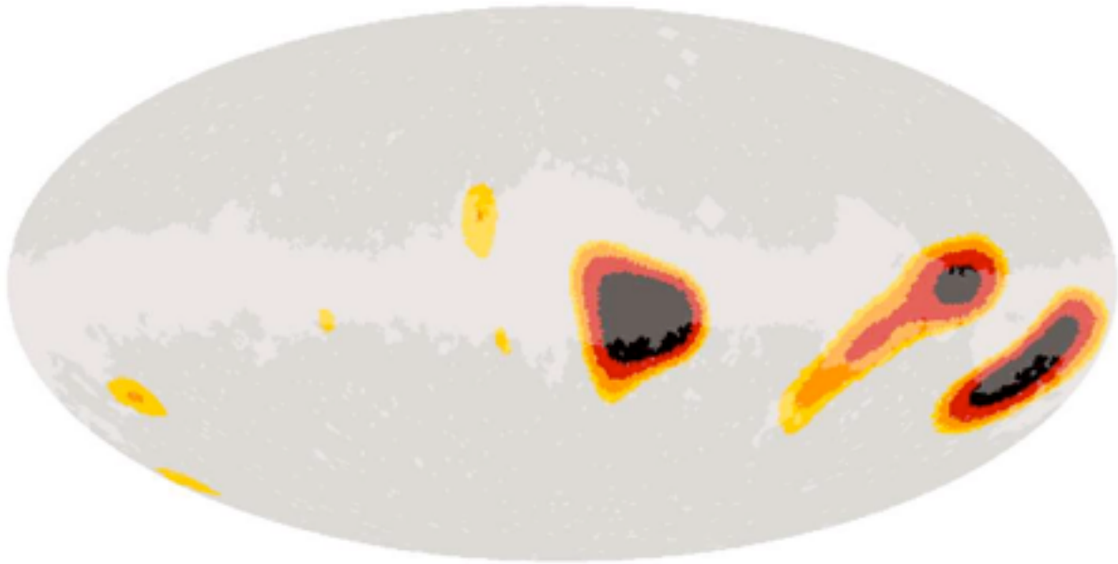
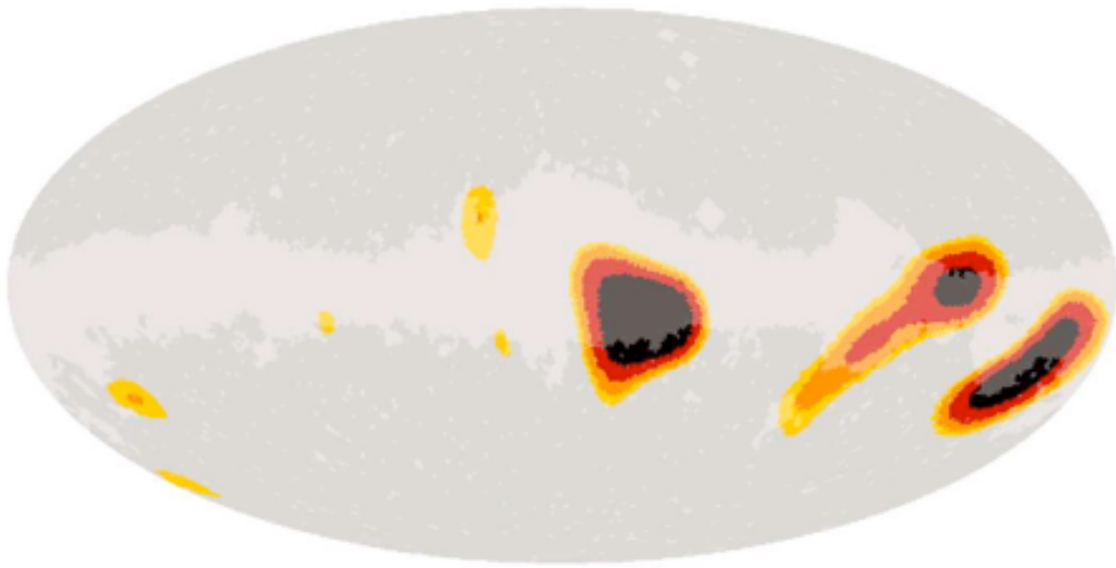


Parity - Cut-Sky Results

(Ben-David, EDK and Itzhaki, ApJ 2012)

Ely D. Kovetz
Aspen Winter 2012

- Mask out 2.5%-10% outlying pixels:
  - Masked regions near the Galactic plane.



Parity - Cut-Sky Results

(Ben-David, EDK and Itzhaki, ApJ 2012)

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Aspen Winter 2012

- Mask out 2.5%-10% outlying pixels:
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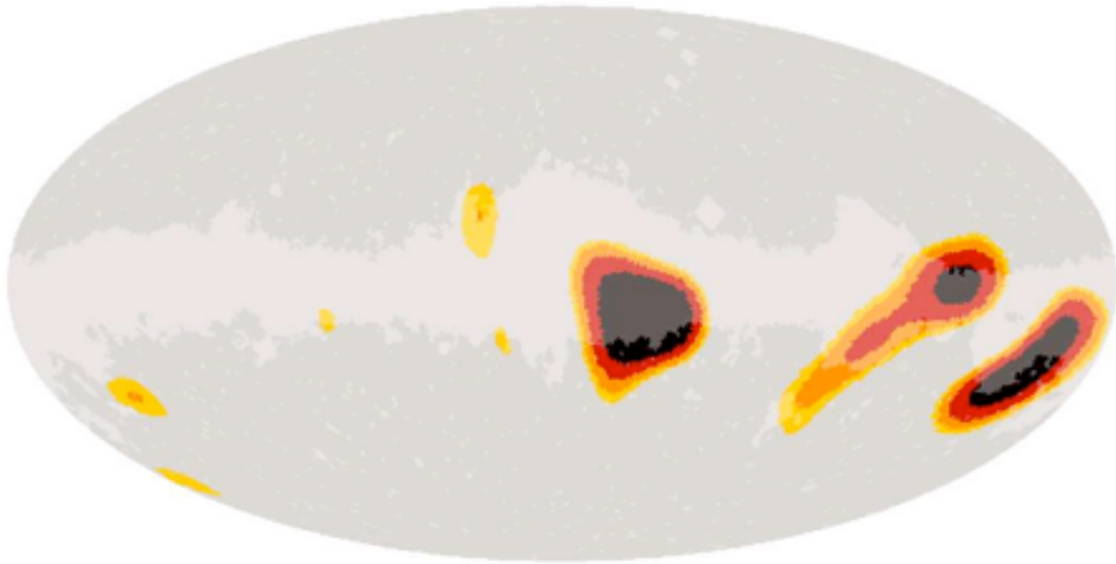
  - Procedure applicable to random maps.



Parity - Cut-Sky Results

(Ben-David, EDK and Itzhaki, ApJ 2012)

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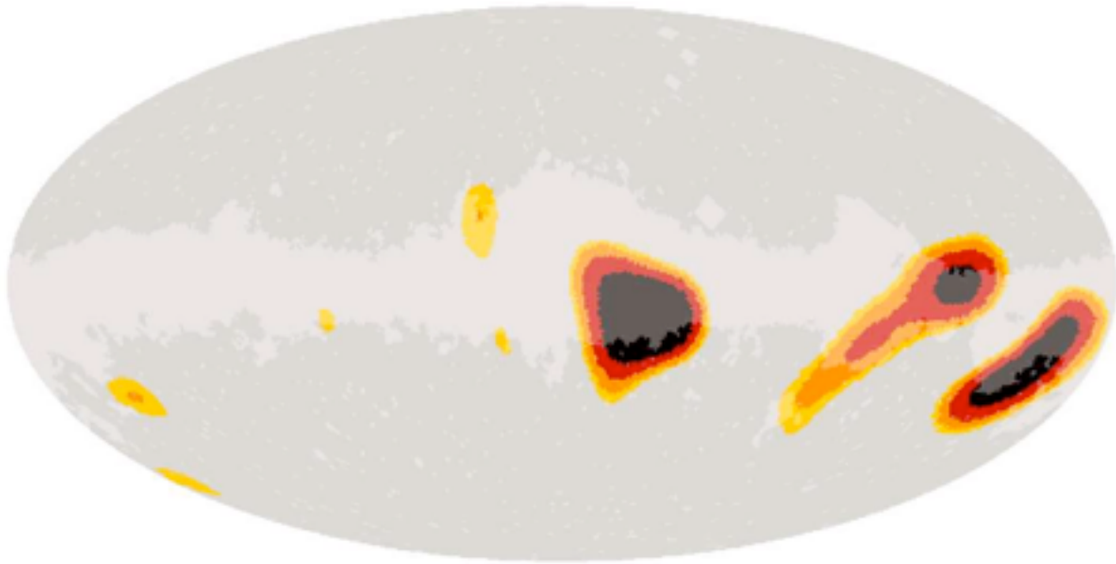

- With all masks (including KQ75/85), we find:

Parity - Cut-Sky Results

(Ben-David, EDK and Itzhaki, ApJ 2012)

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Aspen Winter 2012

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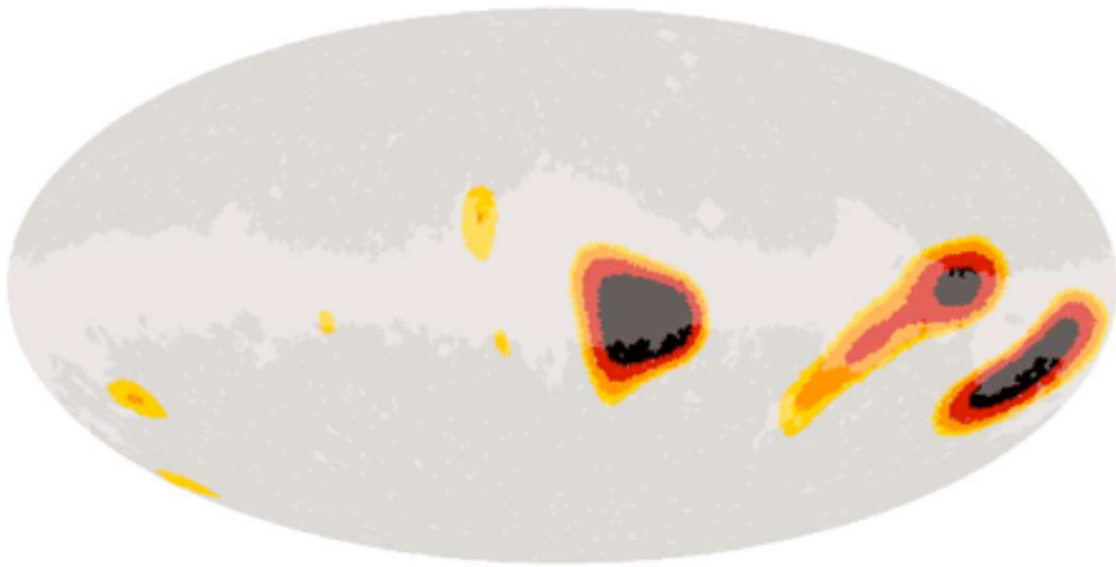
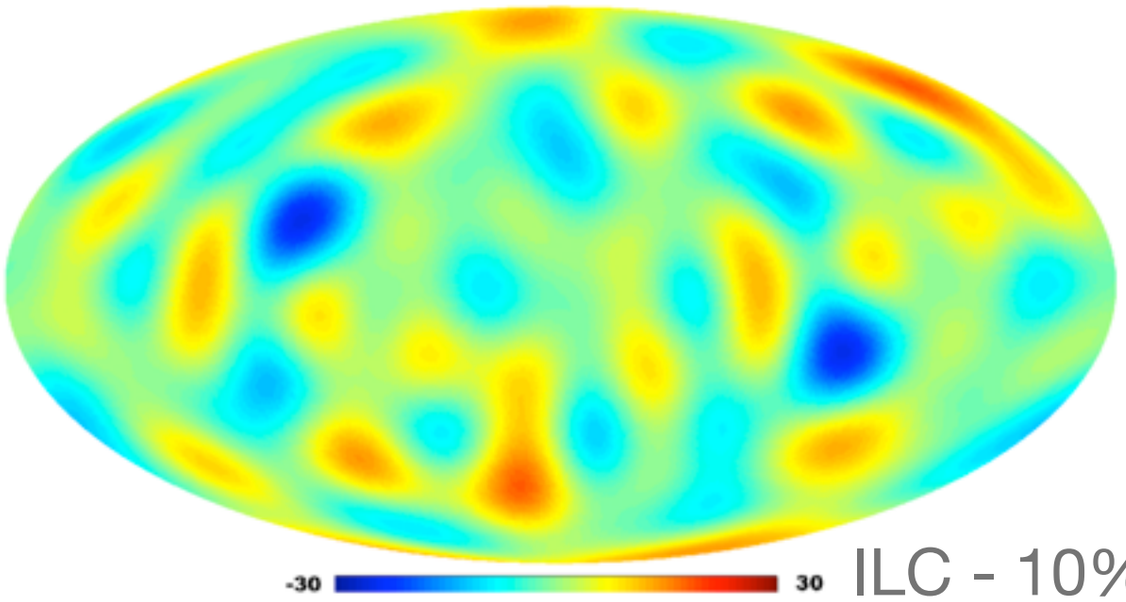


- With all masks (including KQ75/85), we find:



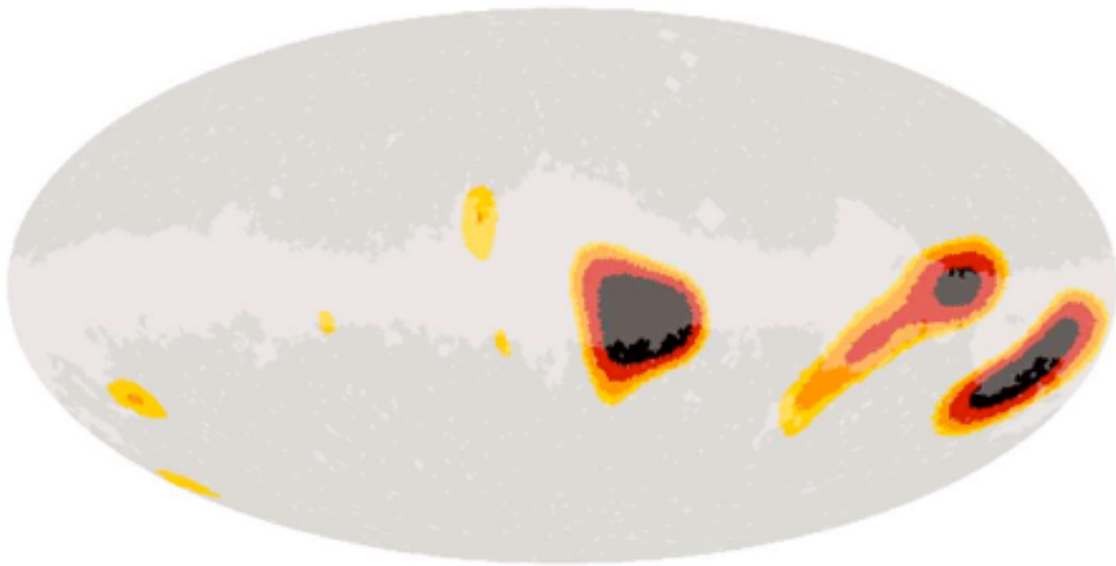
ILC - 10%

Parity - Cut-Sky Results

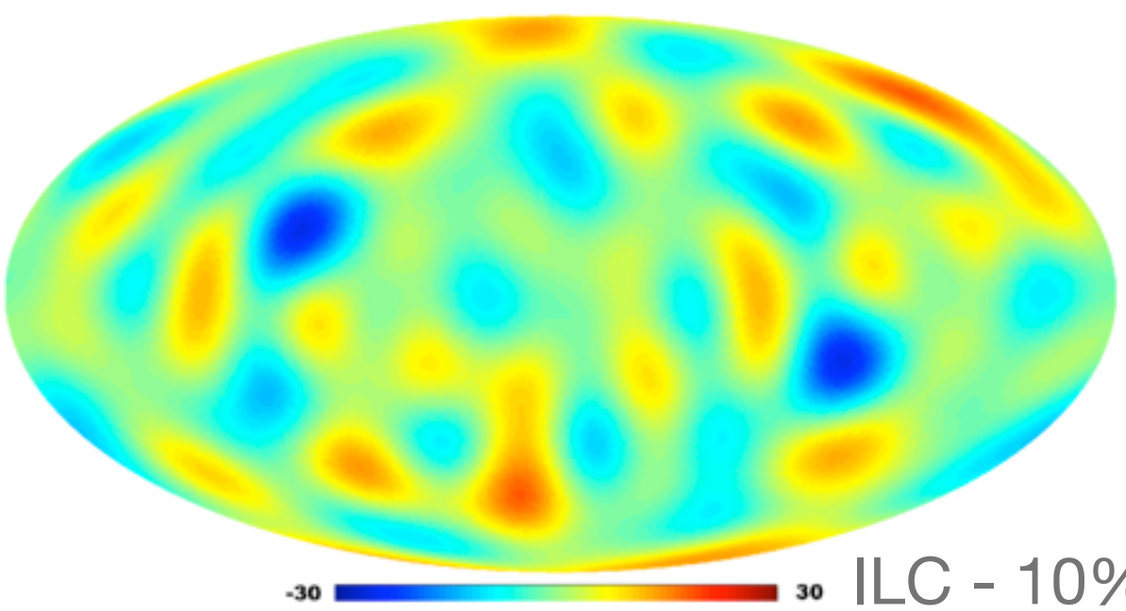
(Ben-David, EDK and Itzhaki, ApJ 2012)

Ely D. Kovetz
Aspen Winter 2012

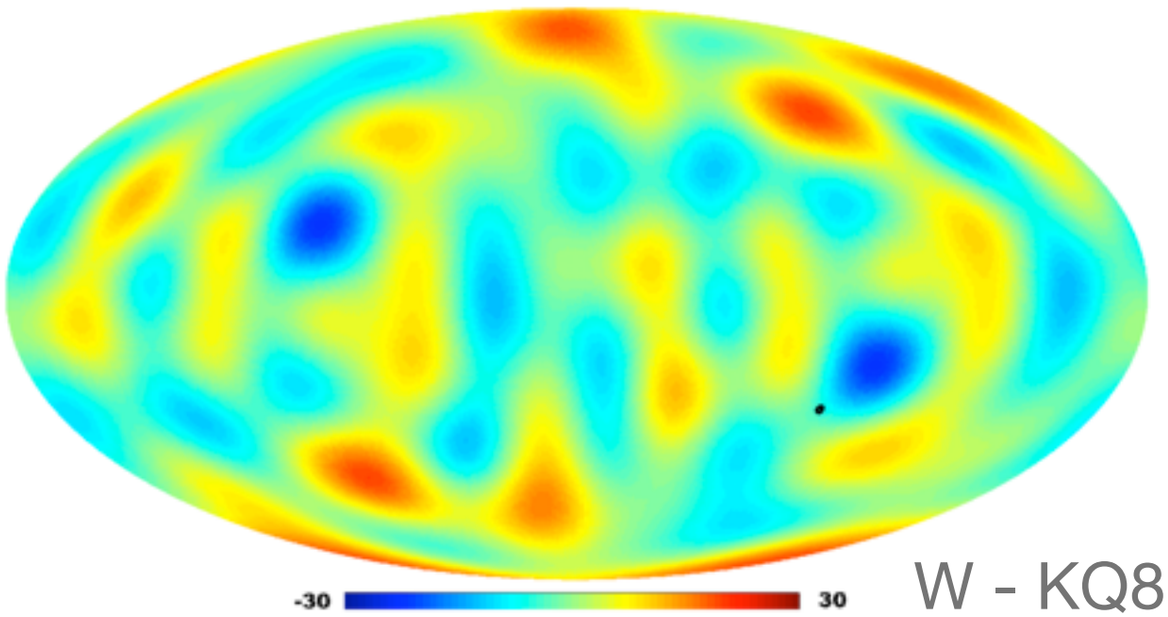
- Mask out 2.5%-10% outlying pixels:
  - Masked regions near the Galactic plane.
  - Procedure applicable to random maps.



- With all masks (including KQ75/85), we find:



ILC - 10%



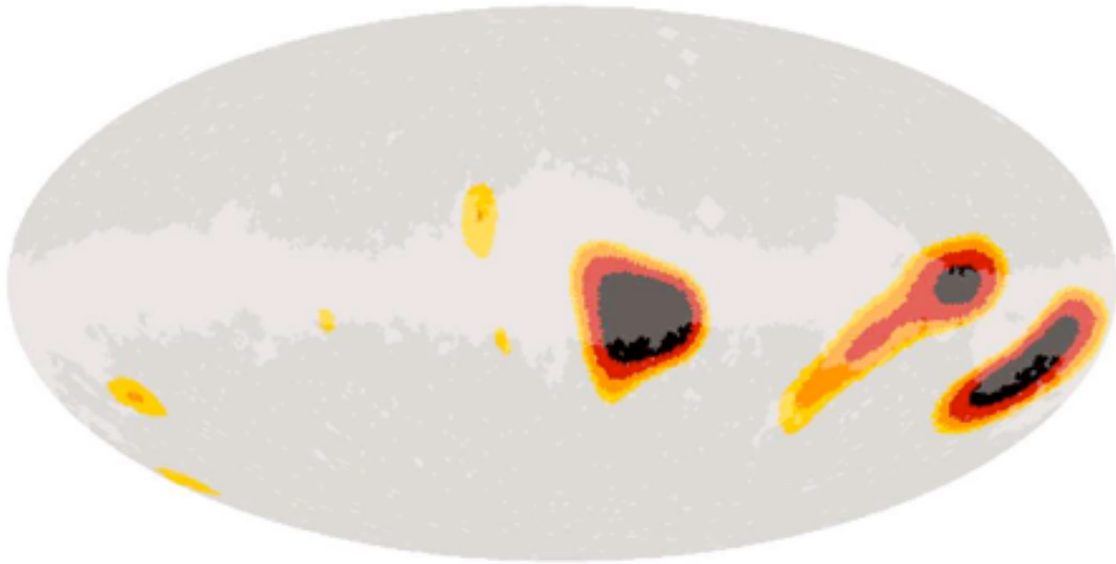
W - KQ85

Parity - Cut-Sky Results

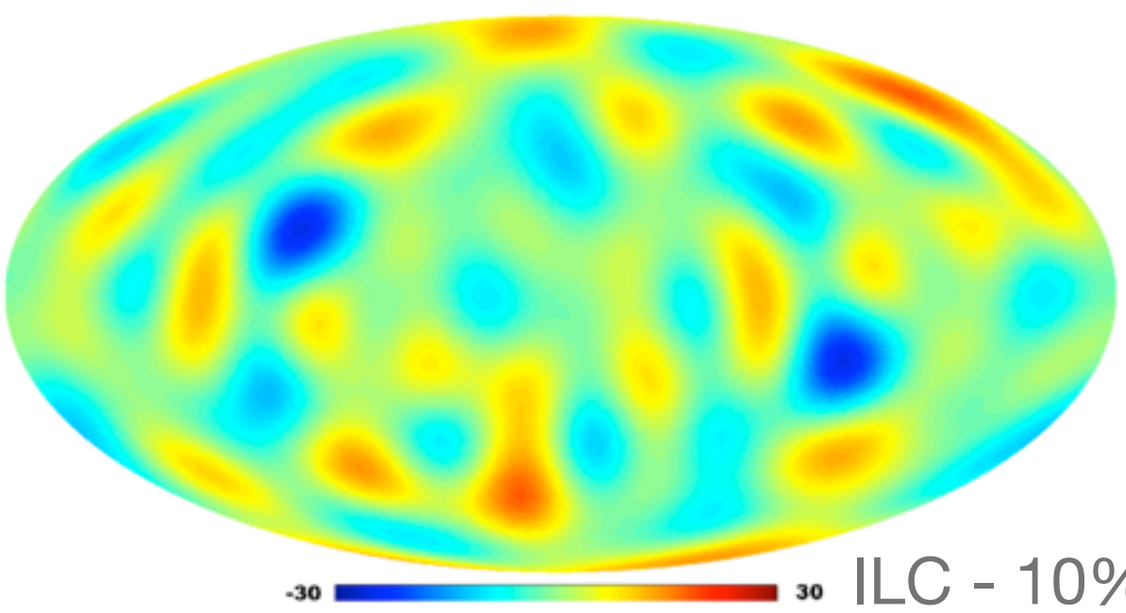
(Ben-David, EDK and Itzhaki, ApJ 2012)

Ely D. Kovetz
Aspen Winter 2012

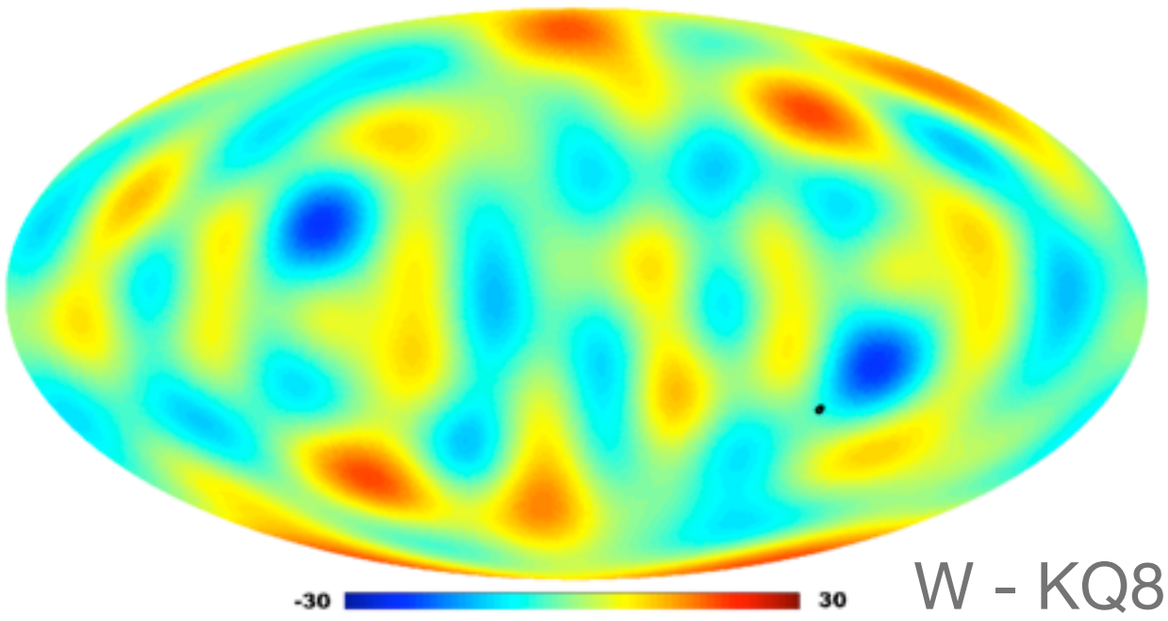
- Mask out 2.5%-10% outlying pixels:
  - Masked regions near the Galactic plane.
  - Procedure applicable to random maps.



- With all masks (including KQ75/85), we find:



ILC - 10%



W - KQ85

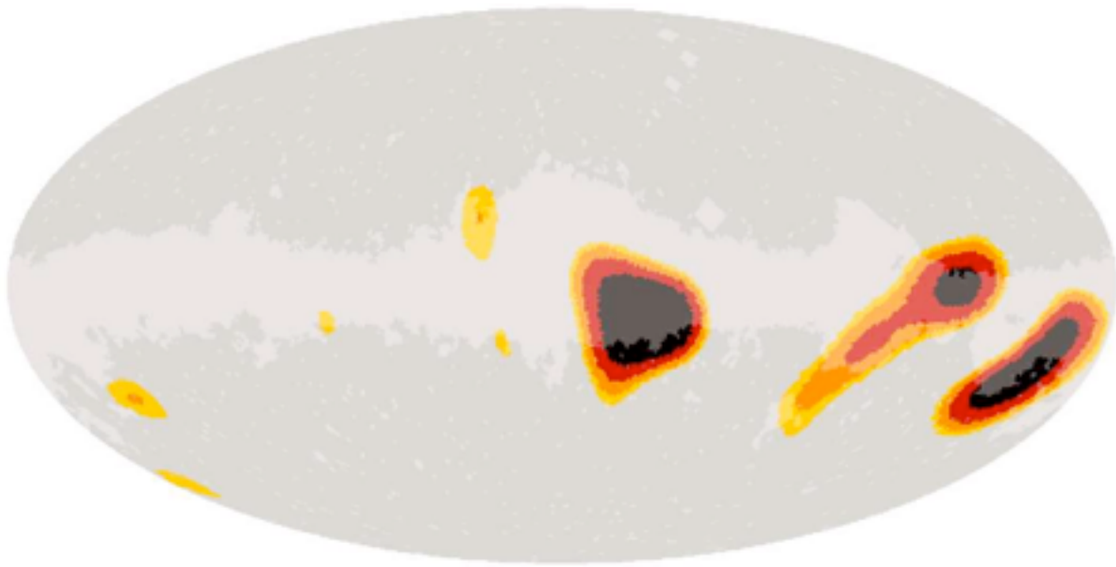
  - Even parity insignificant.

Parity - Cut-Sky Results

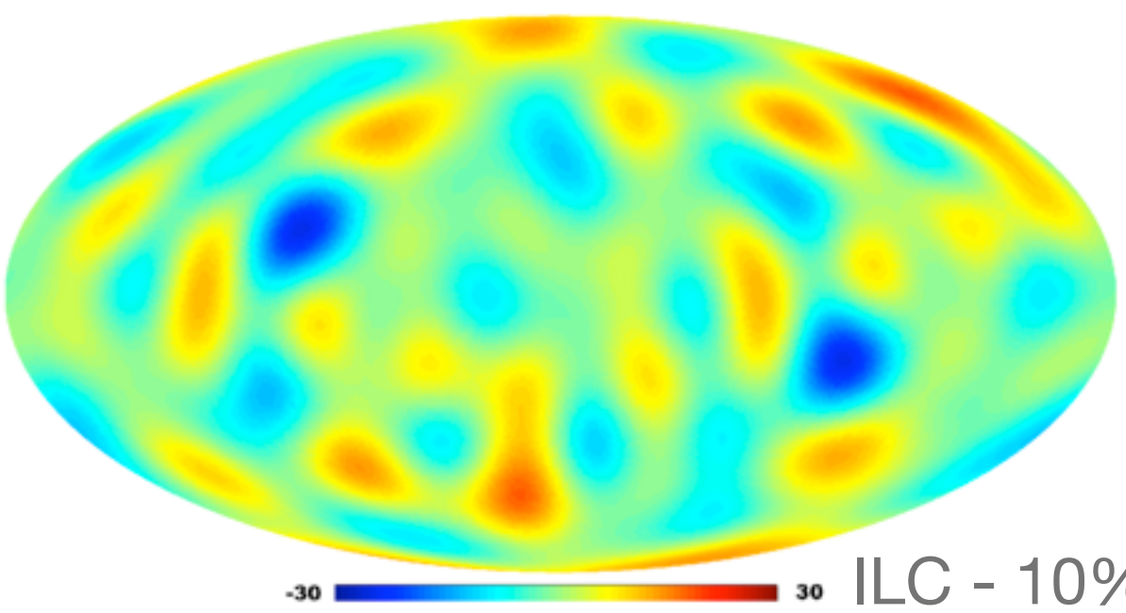
(Ben-David, EDK and Itzhaki, ApJ 2012)

Ely D. Kovetz
Aspen Winter 2012

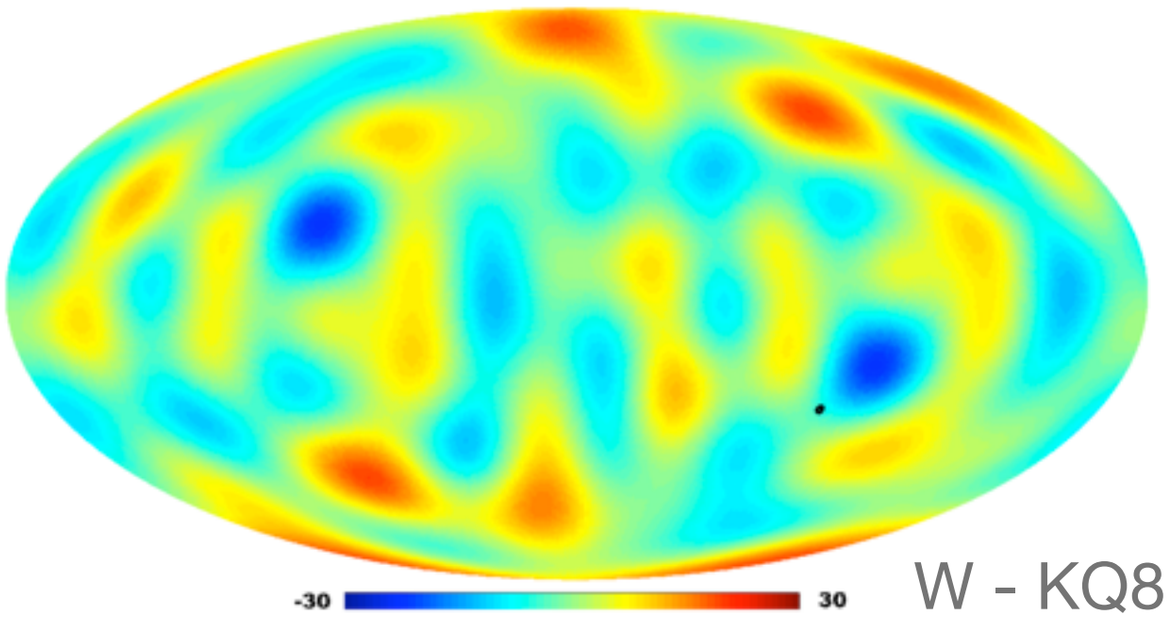
- Mask out 2.5%-10% outlying pixels:
  - Masked regions near the Galactic plane.
  - Procedure applicable to random maps.



- With all masks (including KQ75/85), we find:



ILC - 10%



W - KQ85

  - Odd parity at $(l, b) \simeq (264^\circ, -18^\circ)$ is significant: ~0.01% for $\ell_{max} = 5 - 7$.

Parity - COBE-DMR

Ely D. Kovetz

Aspen Winter 2012

Parity - COBE-DMR

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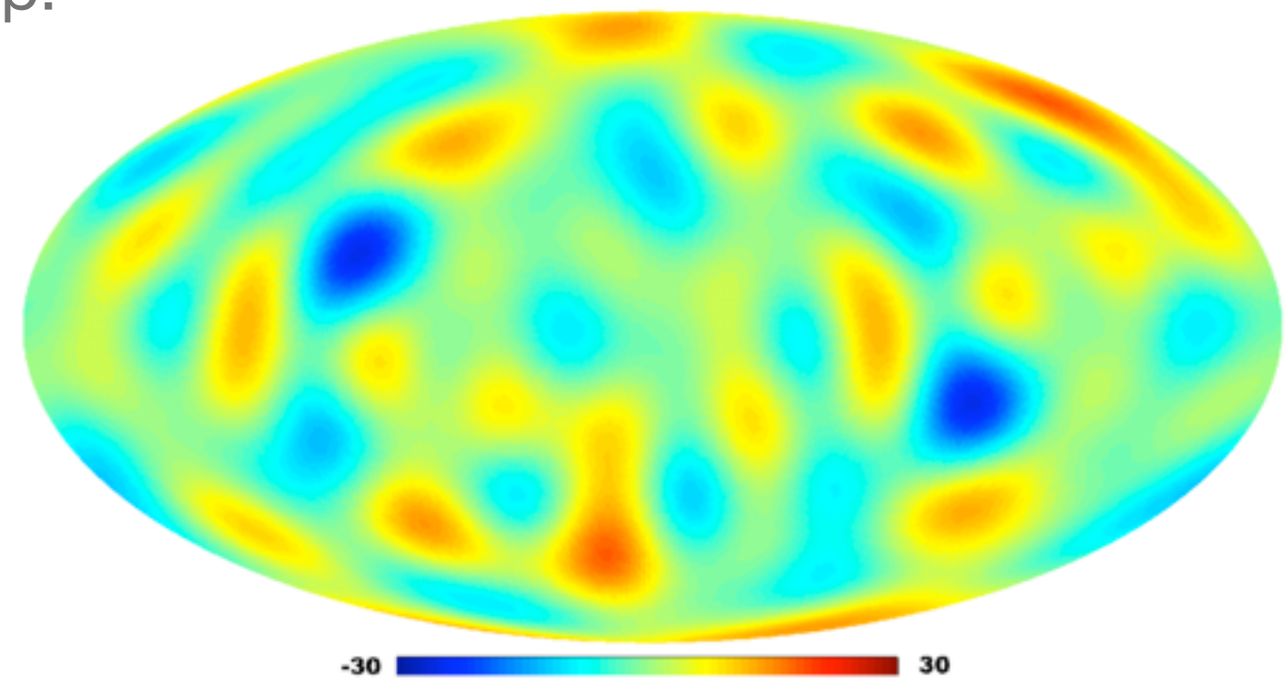
Aspen Winter 2012

- WMAP parity map:



Parity - COBE-DMR

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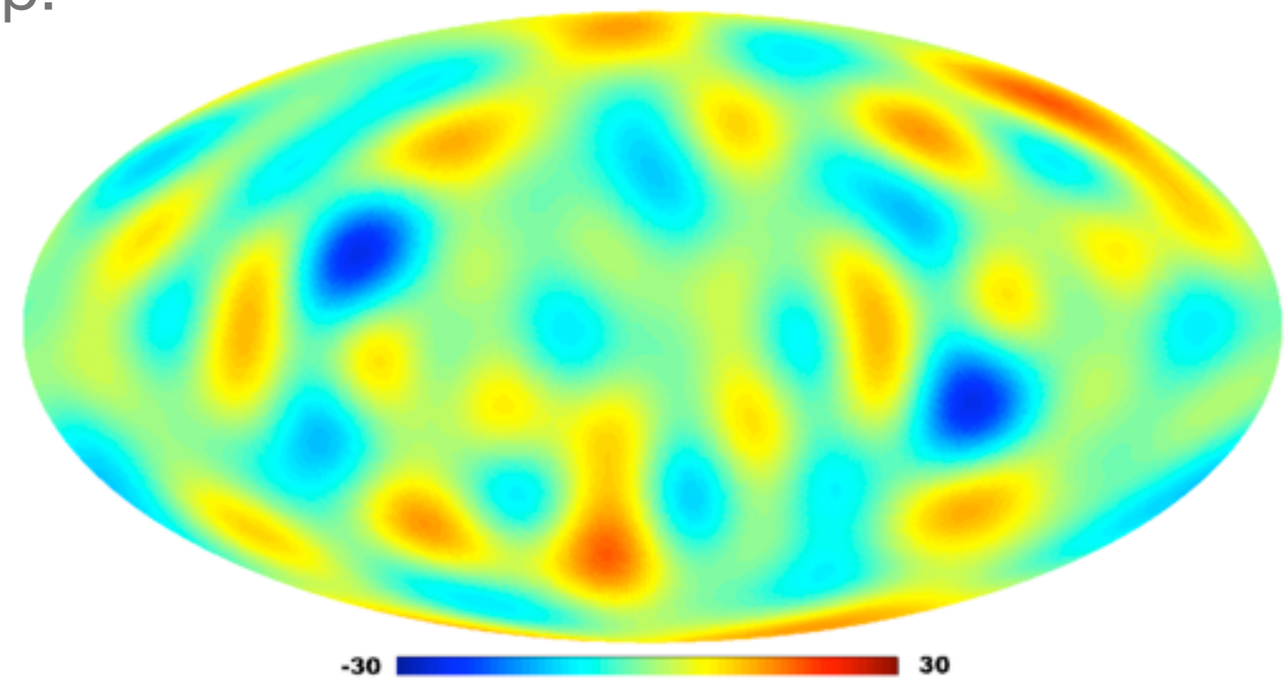
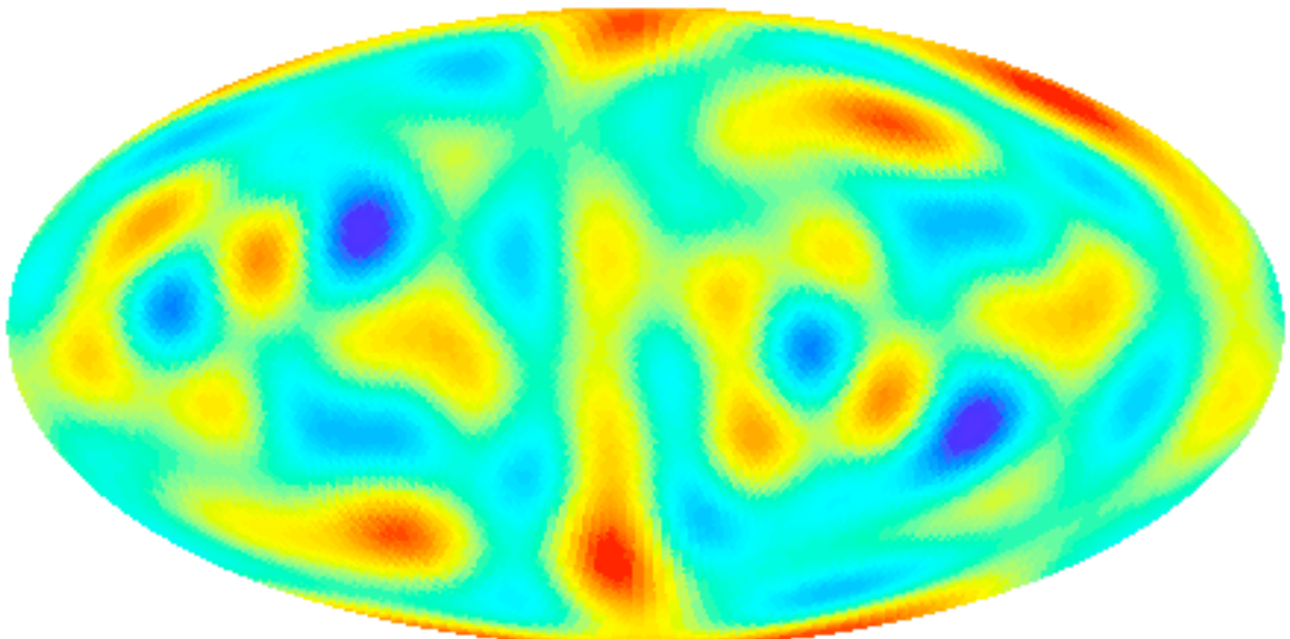
- WMAP parity map:



- COBE parity map:



Simulation vs. data: Moving PIP

Ely D. Kovetz

Aspen Winter 2012

Simulation vs. data: Moving PIP

Ely D. Kovetz
Aspen Winter 2012

Simulating LCDM + a moving PIP (with fine-tuned location and velocity):

Simulation vs. data: Moving PIP

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Aspen Winter 2012

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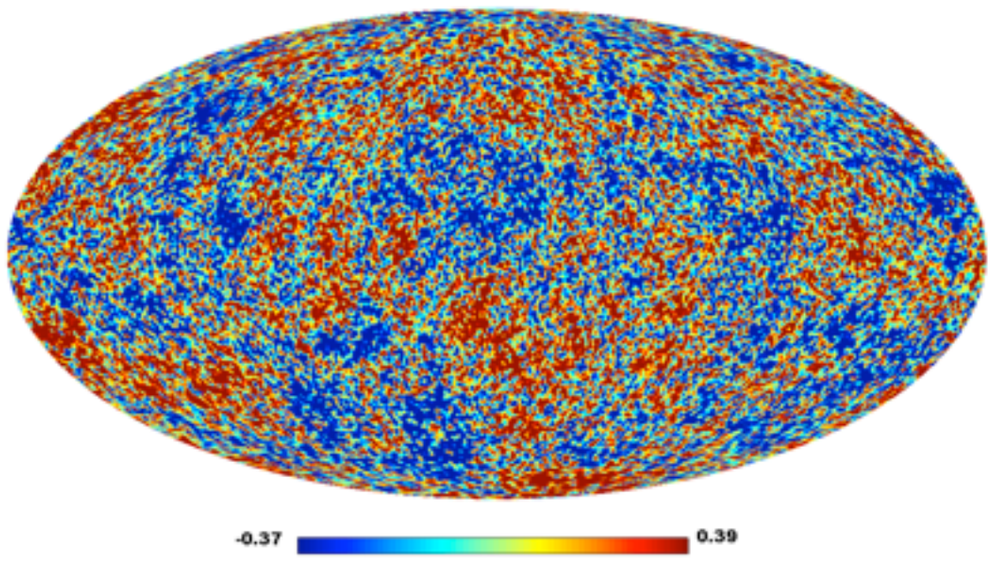

Simulation vs. data: Moving PIP

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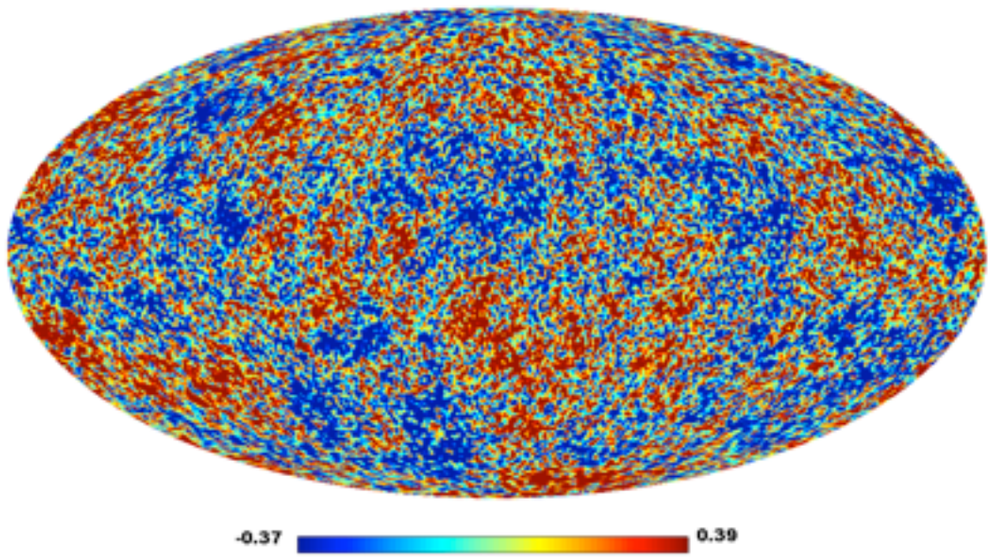

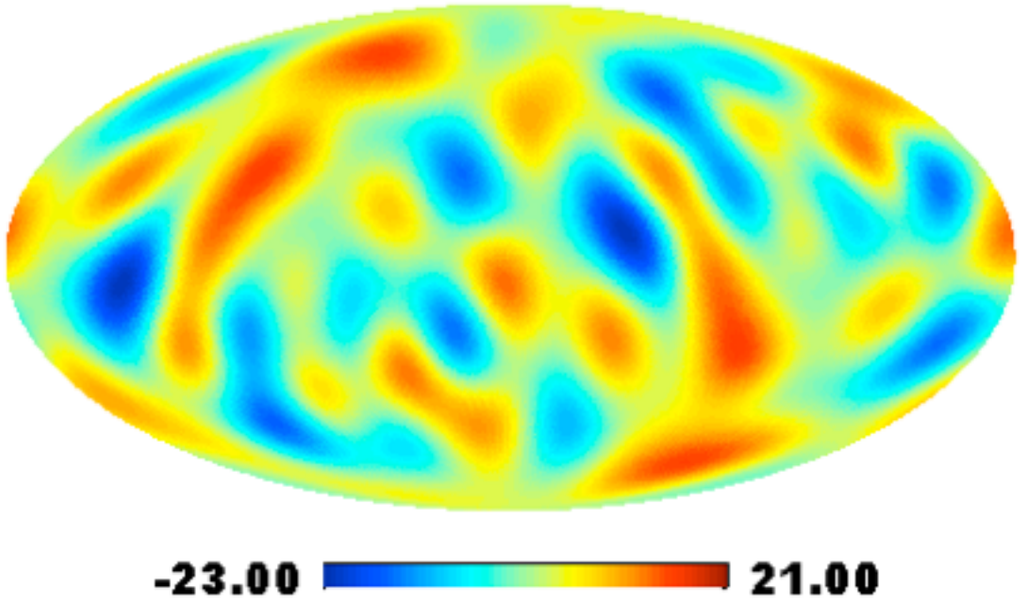

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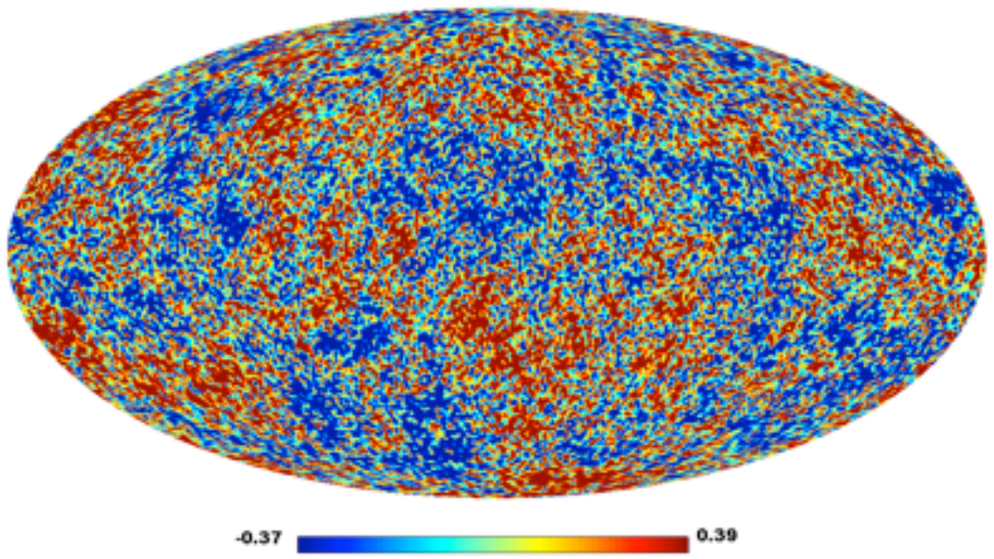

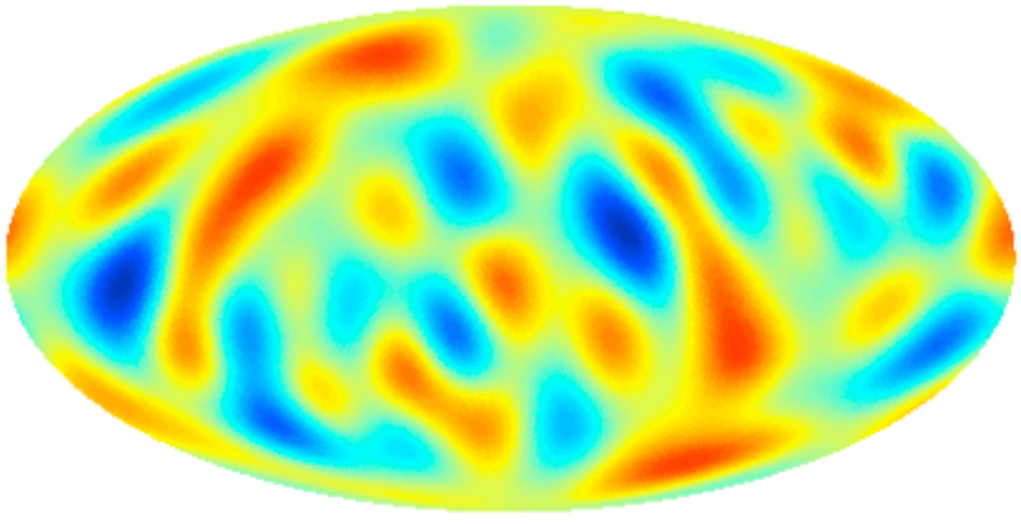

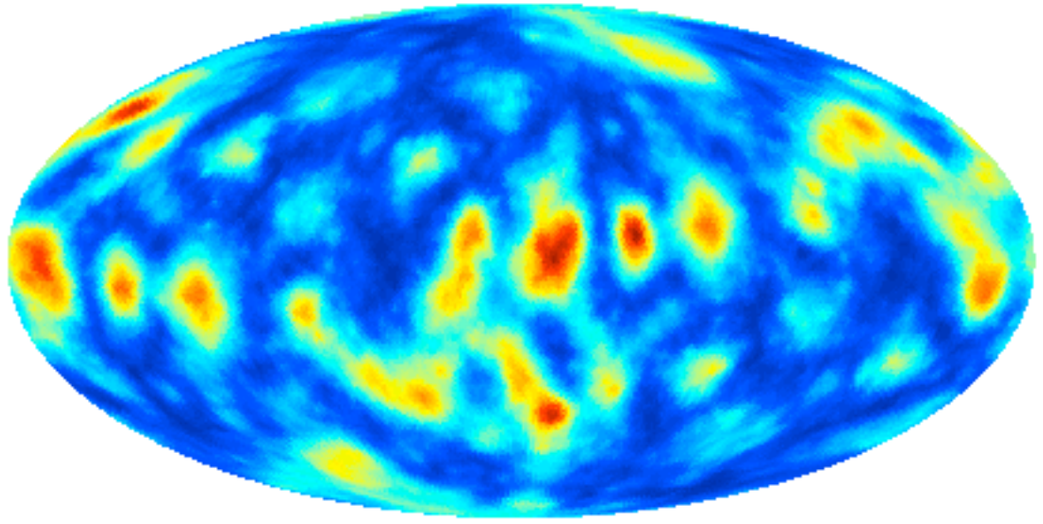

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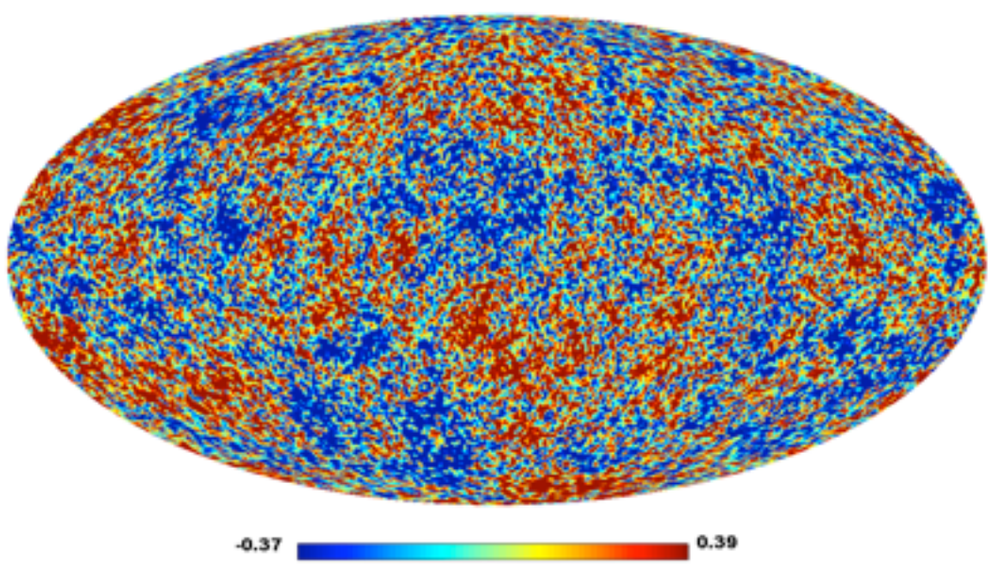

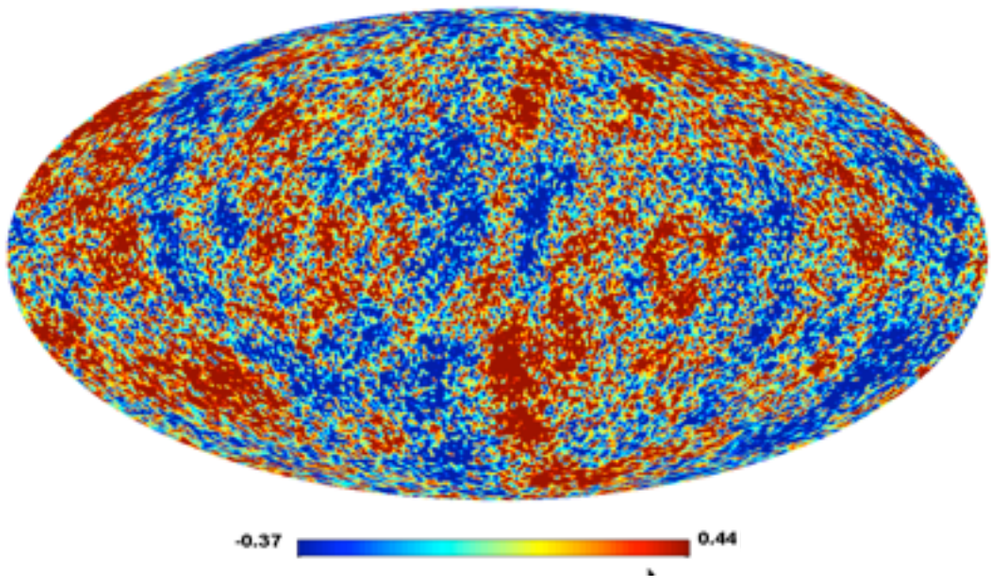

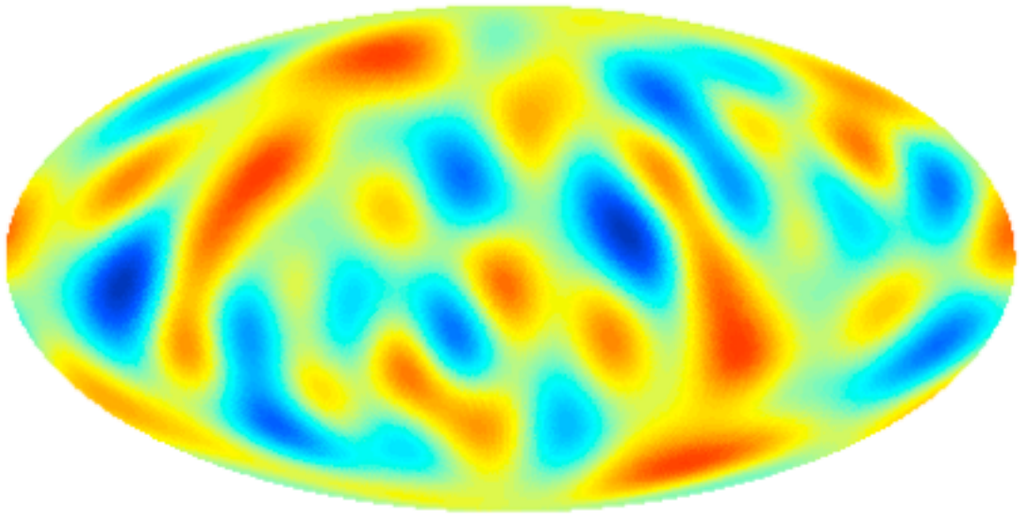

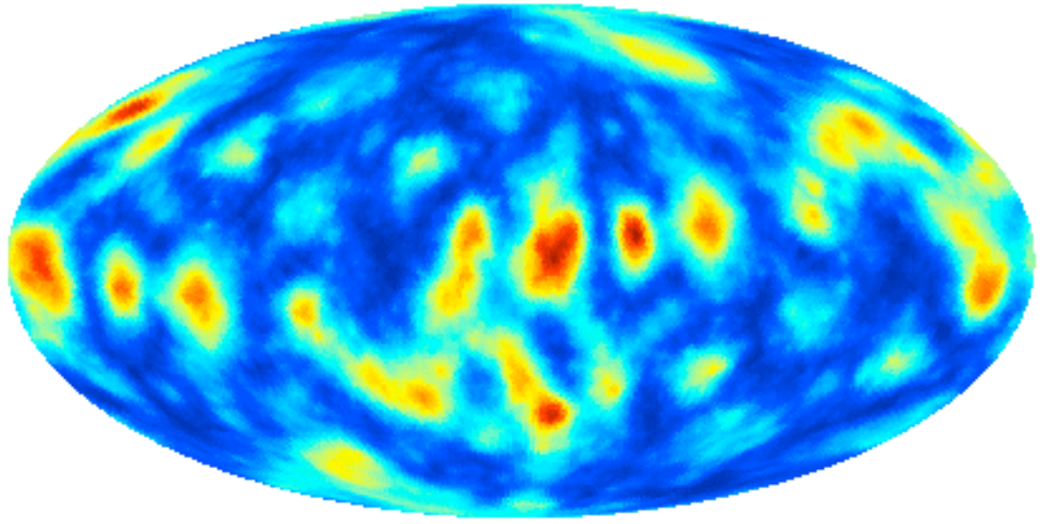

Simulation vs. data: Moving PIP

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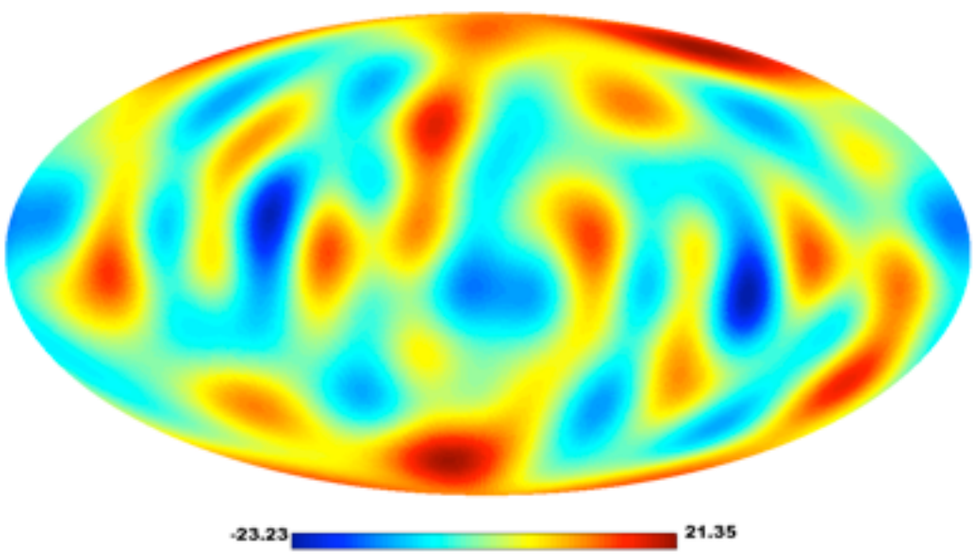
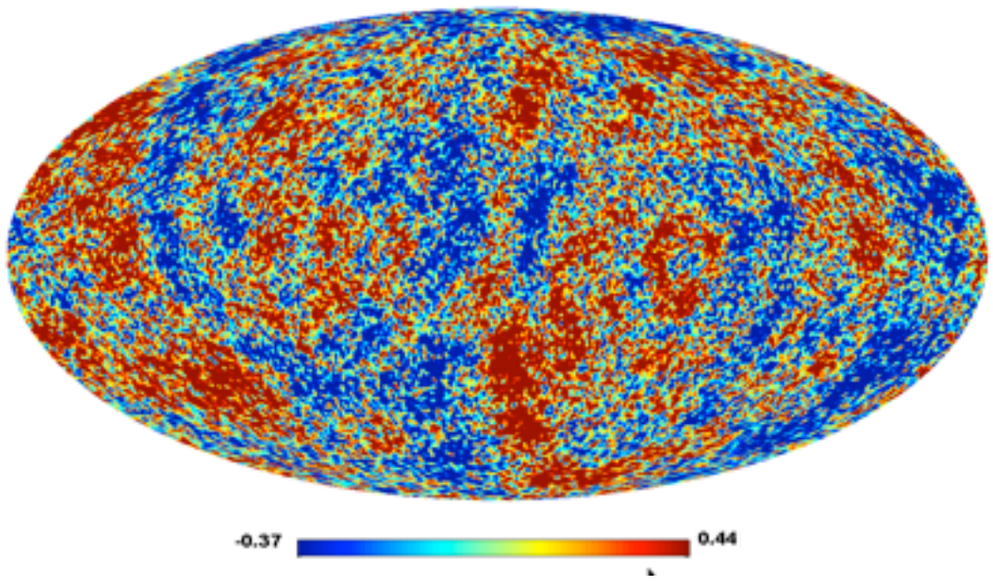
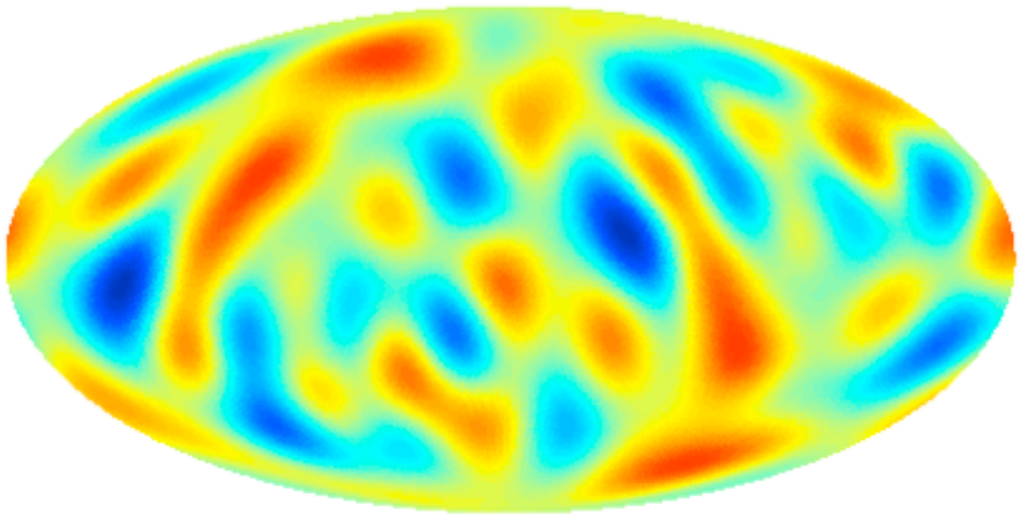
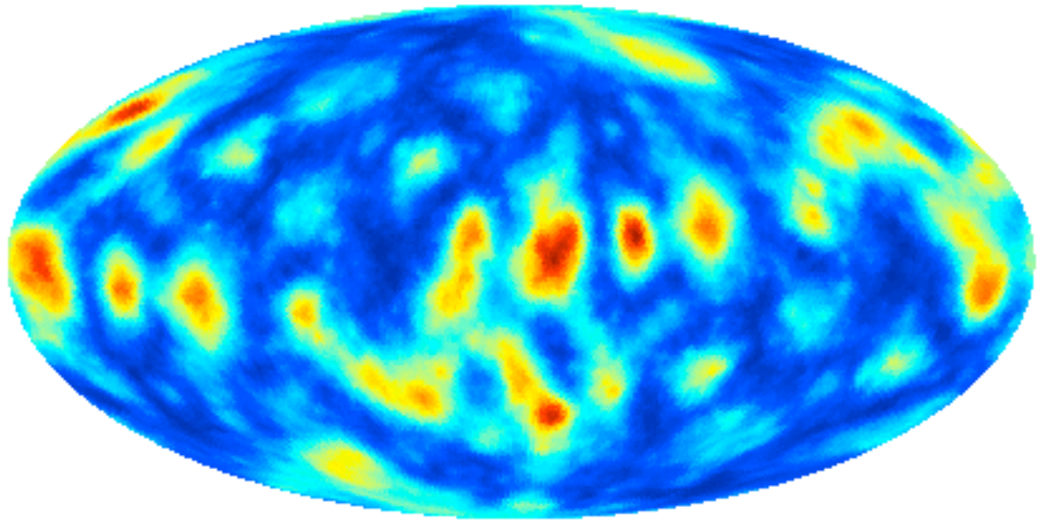
Aspen Winter 2012

Simulating LCDM + a moving PIP (with fine-tuned location and velocity):









Simulation vs. data: Moving PIP

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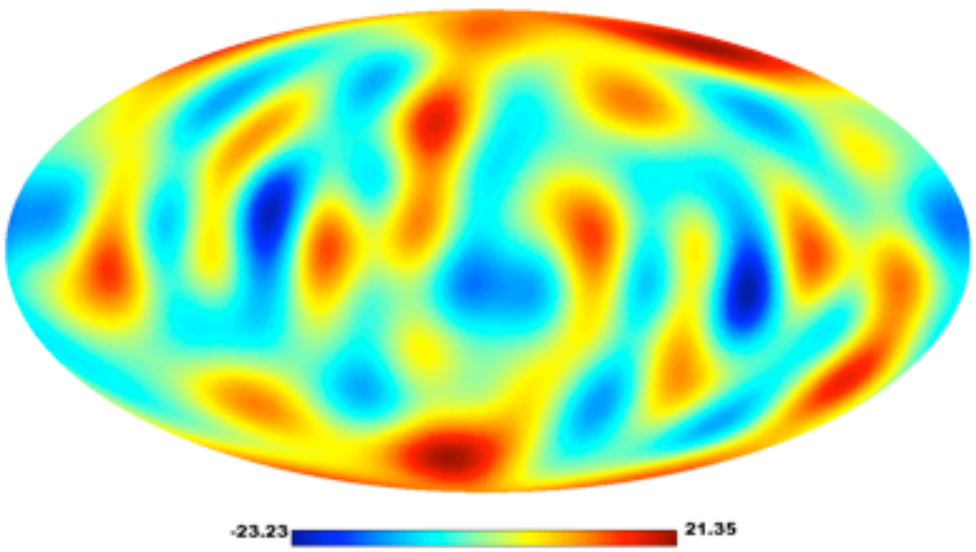
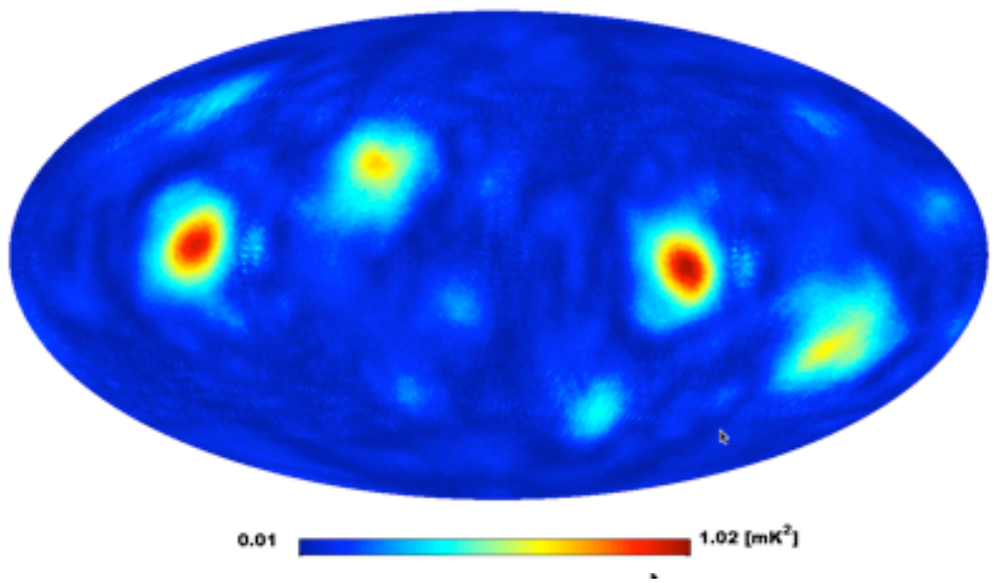
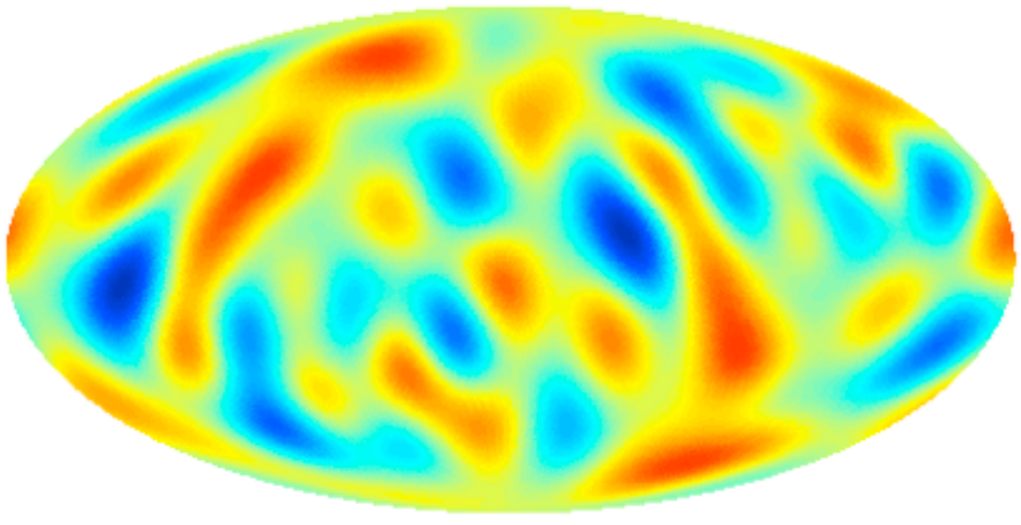
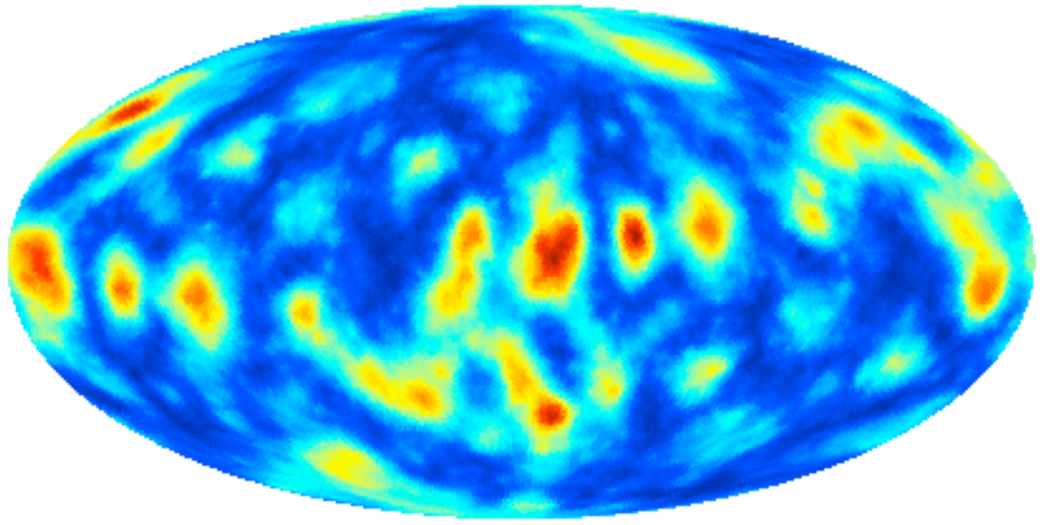
Simulating LCDM + a moving PIP (with fine-tuned location and velocity):









Simulation vs. data: Moving PIP

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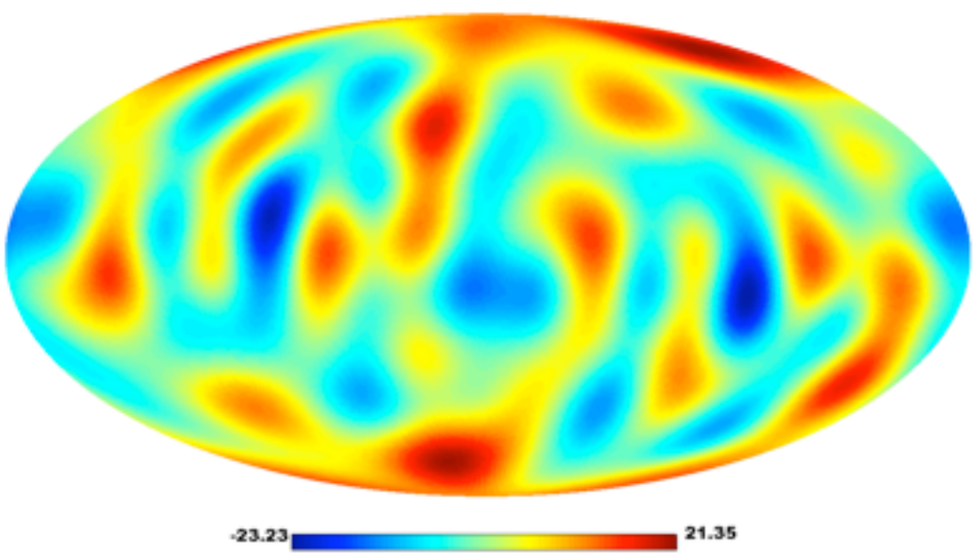
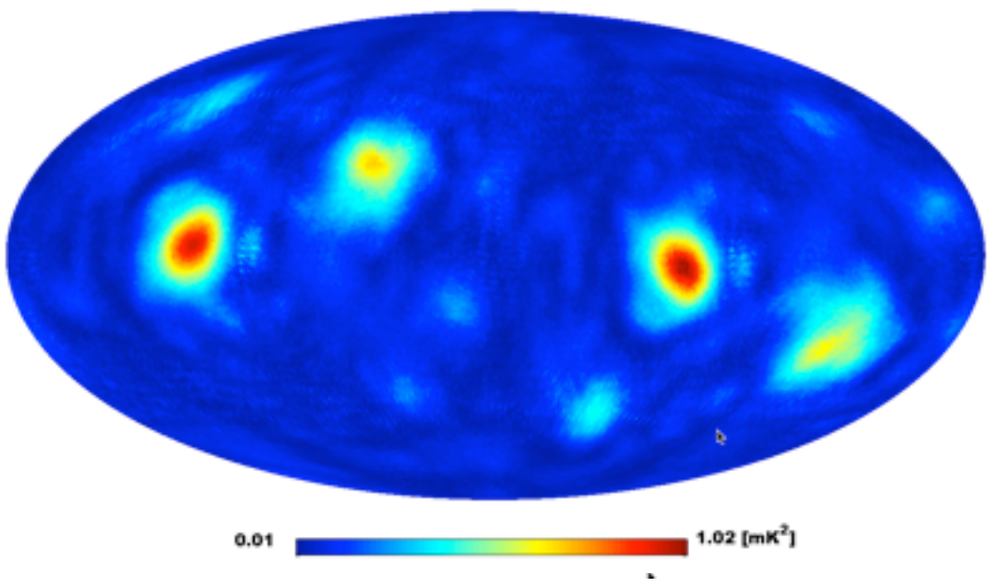
Simulating LCDM + a moving PIP (with fine-tuned location and velocity):



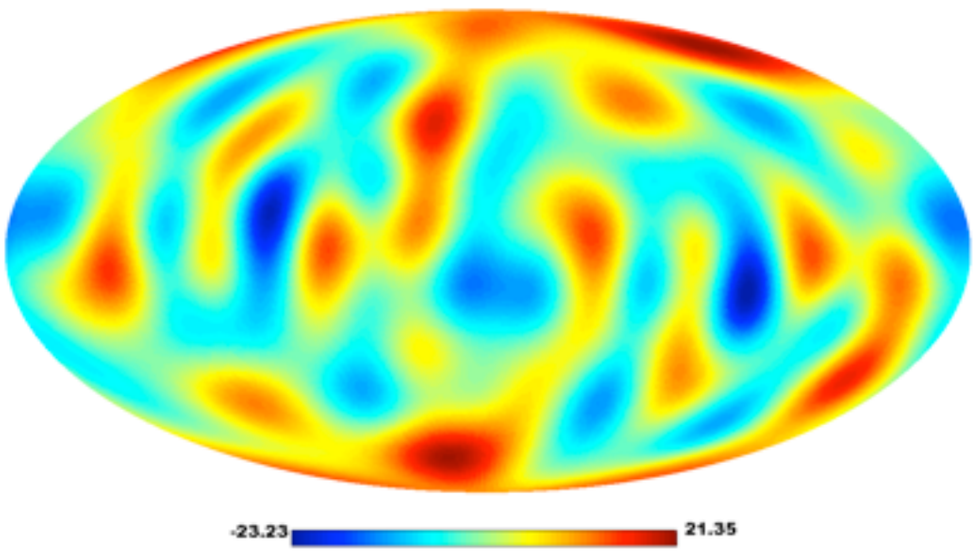


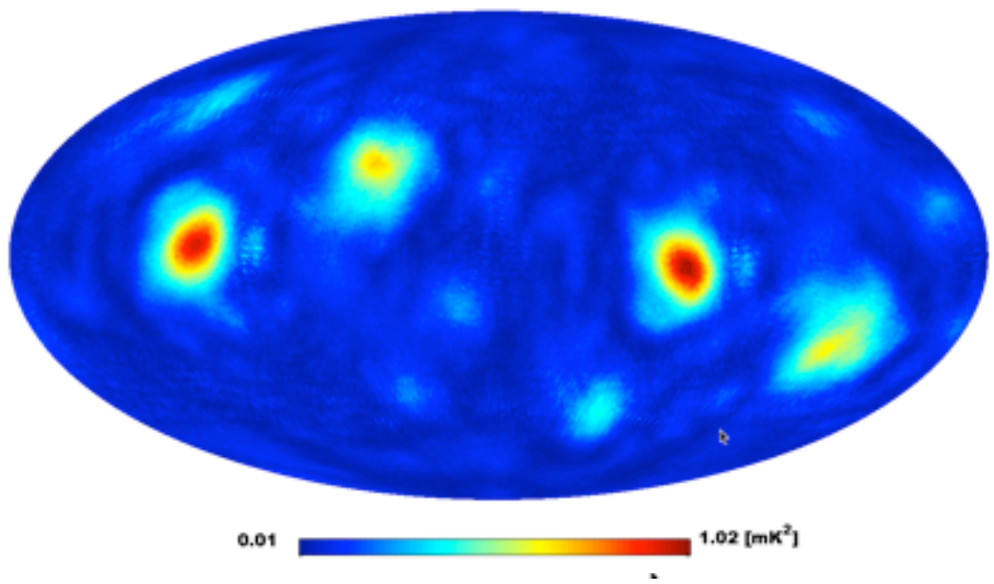
Real data:

Simulation vs. data: Moving PIP

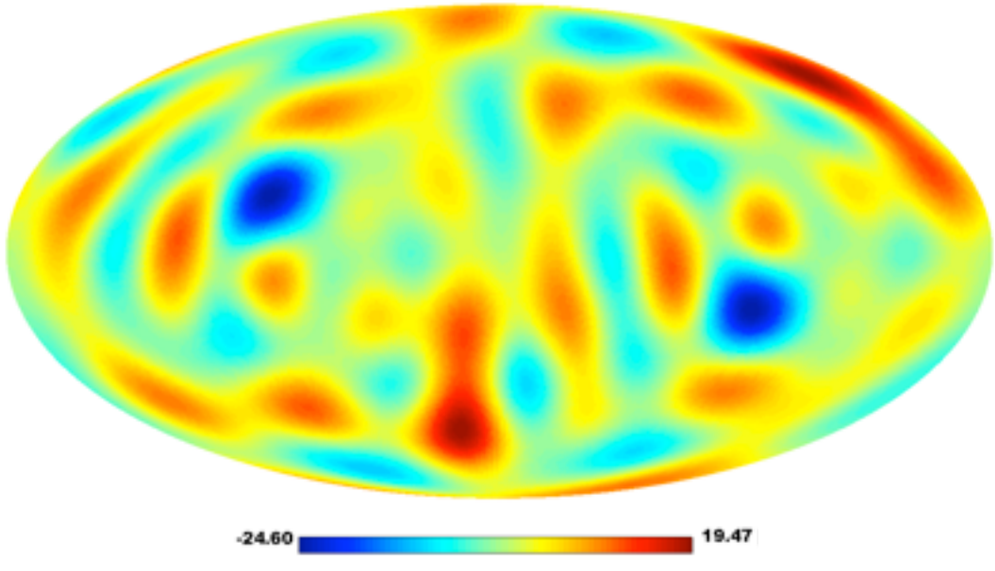
Ely D. Kovetz
Aspen Winter 2012

Simulating LCDM + a moving PIP (with fine-tuned location and velocity):





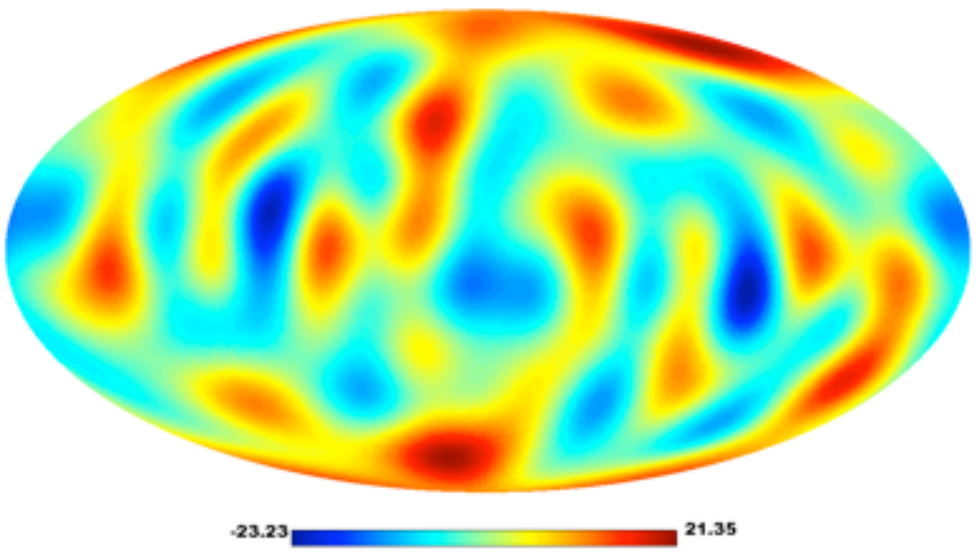
Real data:

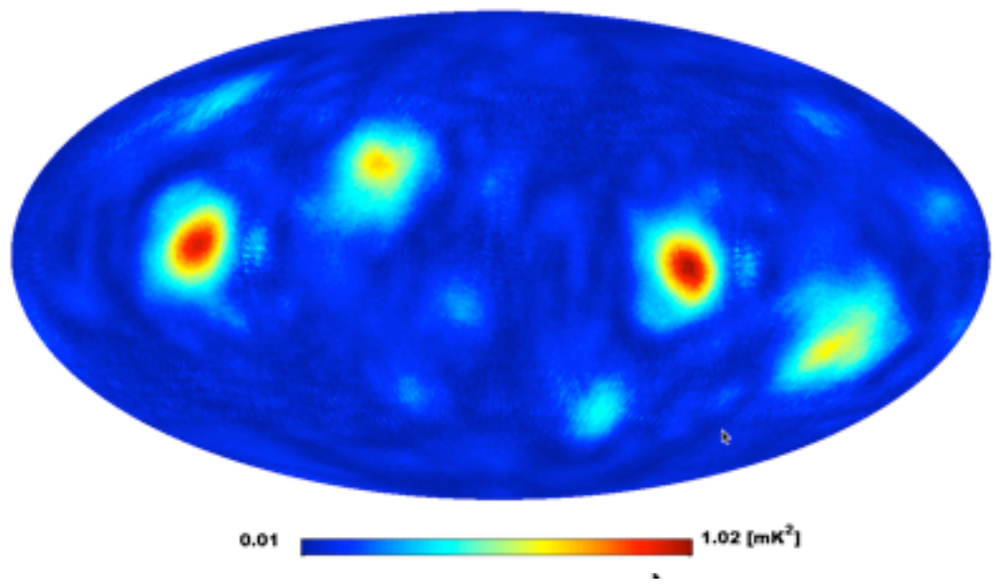


Simulation vs. data: Moving PIP

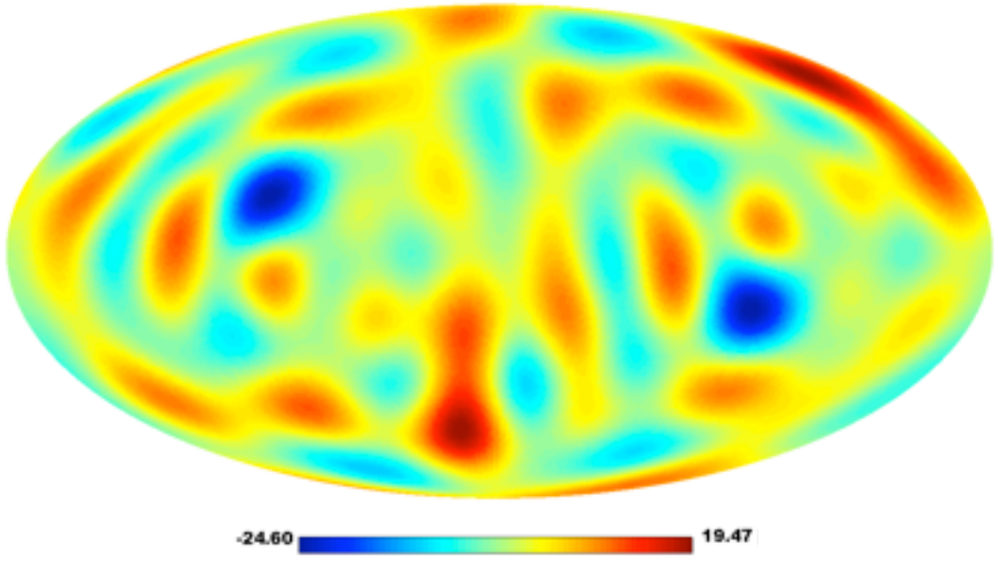
Ely D. Kovetz
Aspen Winter 2012

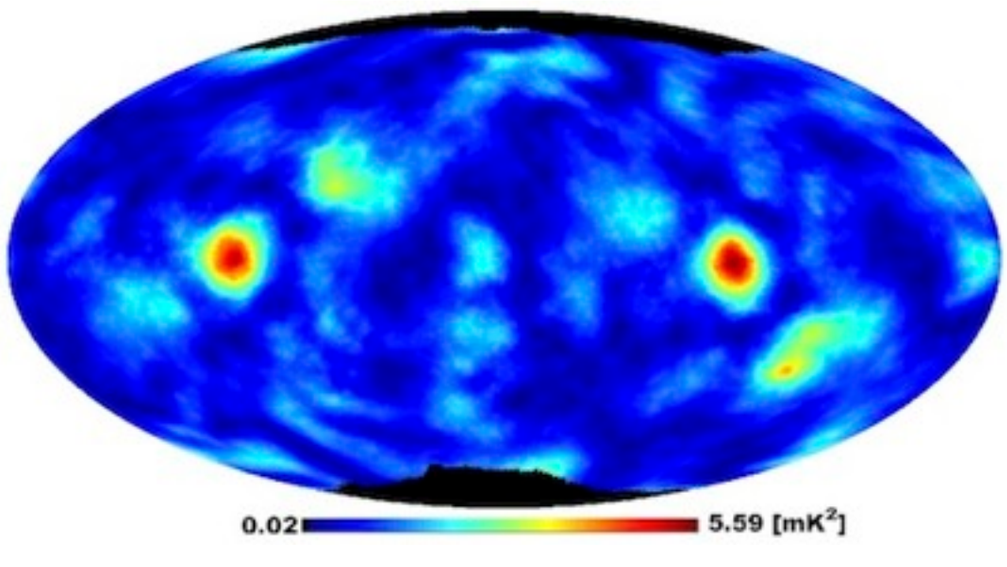
Simulating LCDM + a moving PIP (with fine-tuned location and velocity):





Real data:





Constraining Parameter Space

Ely D. Kovetz

Aspen Winter 2012

Constraining Parameter Space

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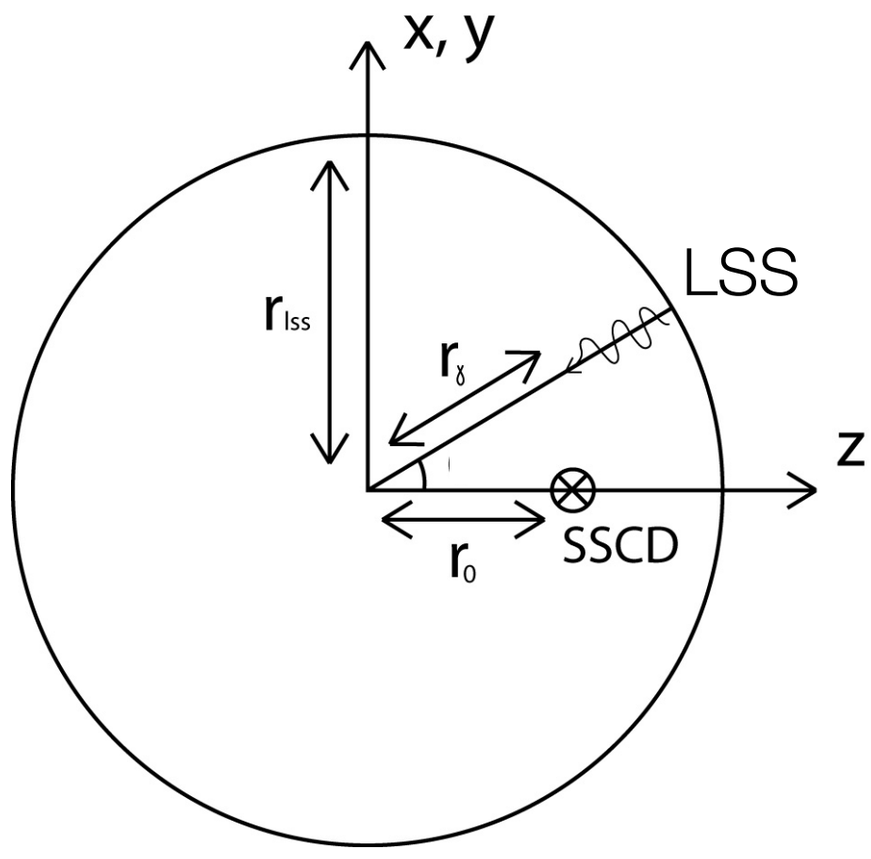
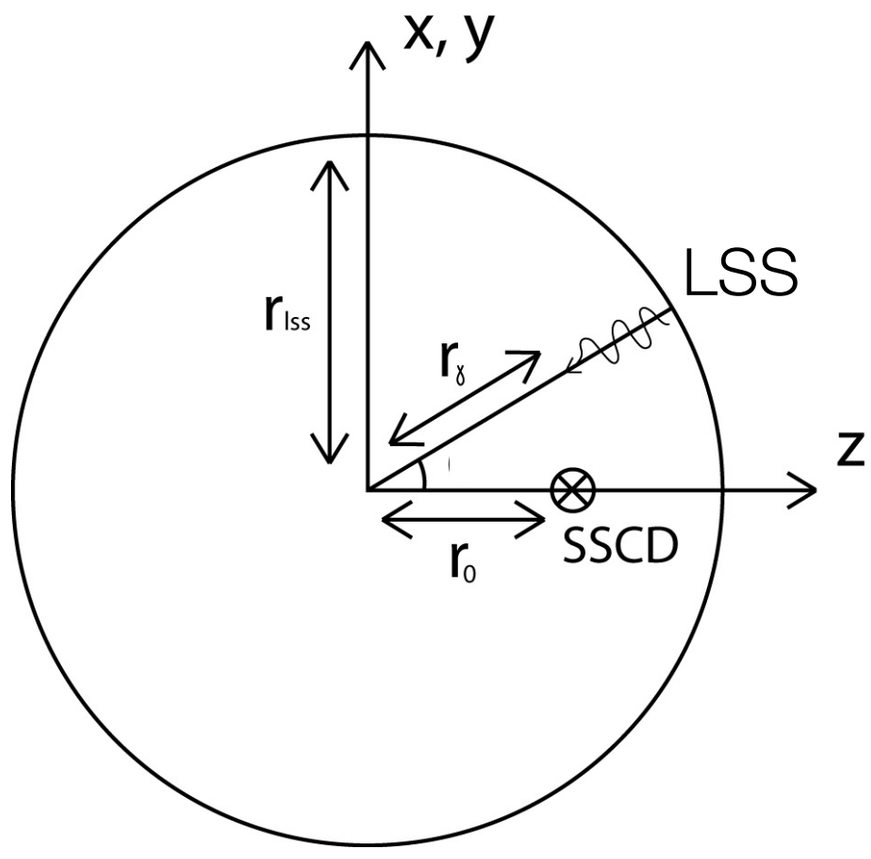


Constraining Parameter Space

Ely D. Kovetz
Aspen Winter 2012

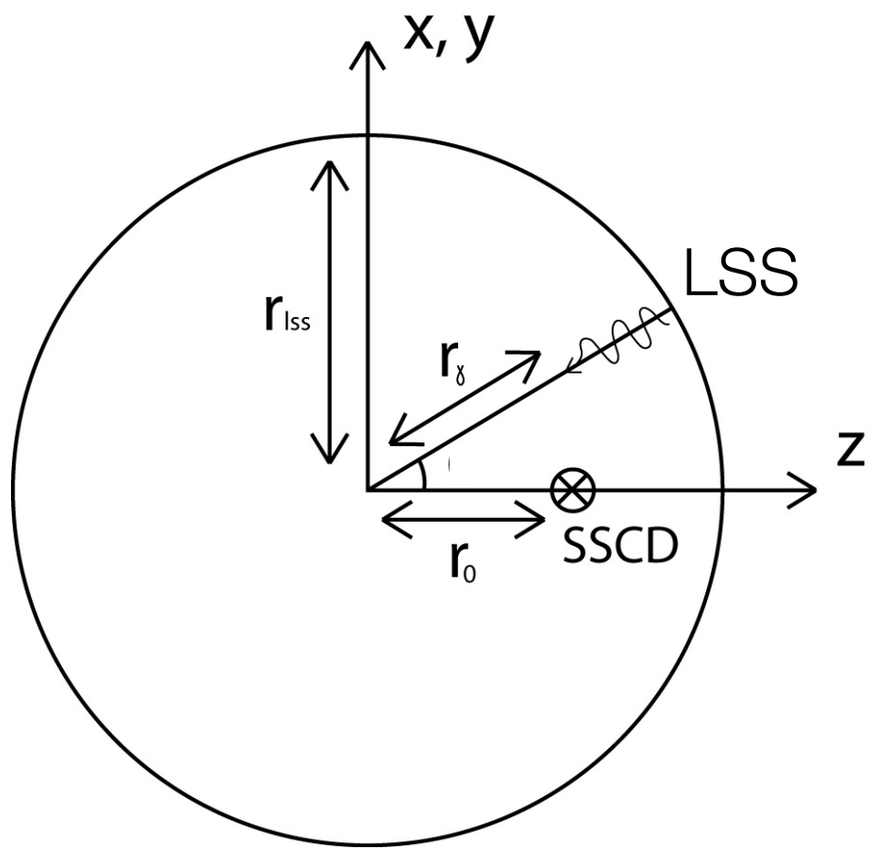
- Constrain the model with magnitude and location of:



Constraining Parameter Space

Ely D. Kovetz
Aspen Winter 2012

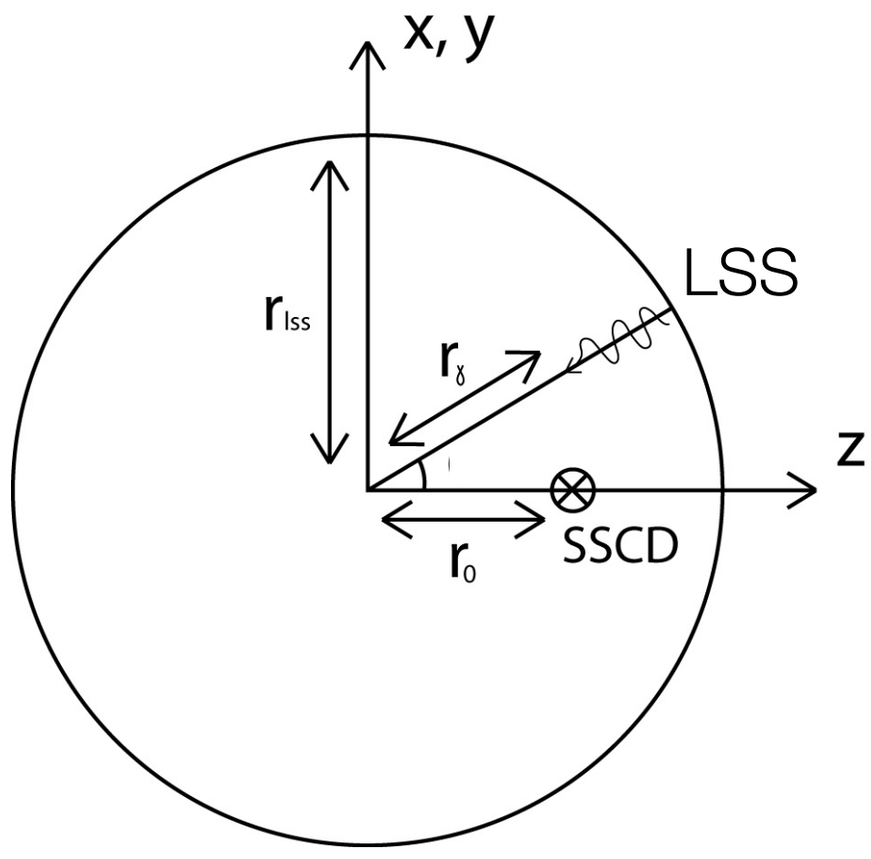
- Constrain the model with magnitude and location of:
  - Giant rings.



Constraining Parameter Space

Ely D. Kovetz
Aspen Winter 2012

- Constrain the model with magnitude and location of:
  - Giant rings.
  - Bulk flow.



Constraining Parameter Space

Ely D. Kovetz
Aspen Winter 2012

- Constrain the model with magnitude and location of:
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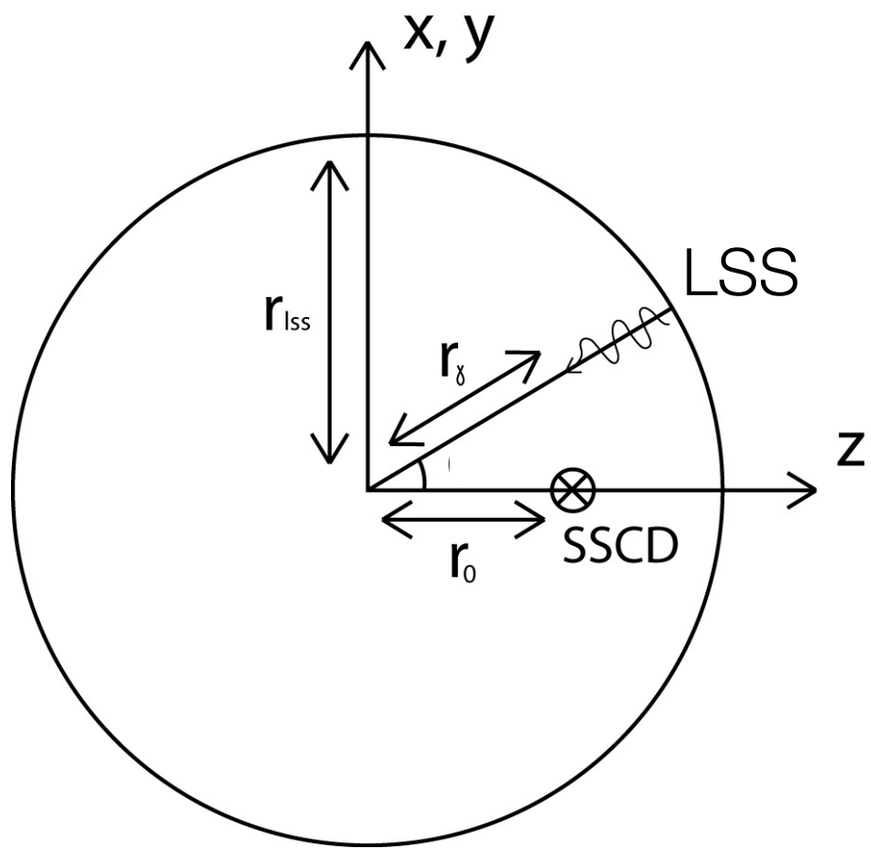
  - Odd parity.



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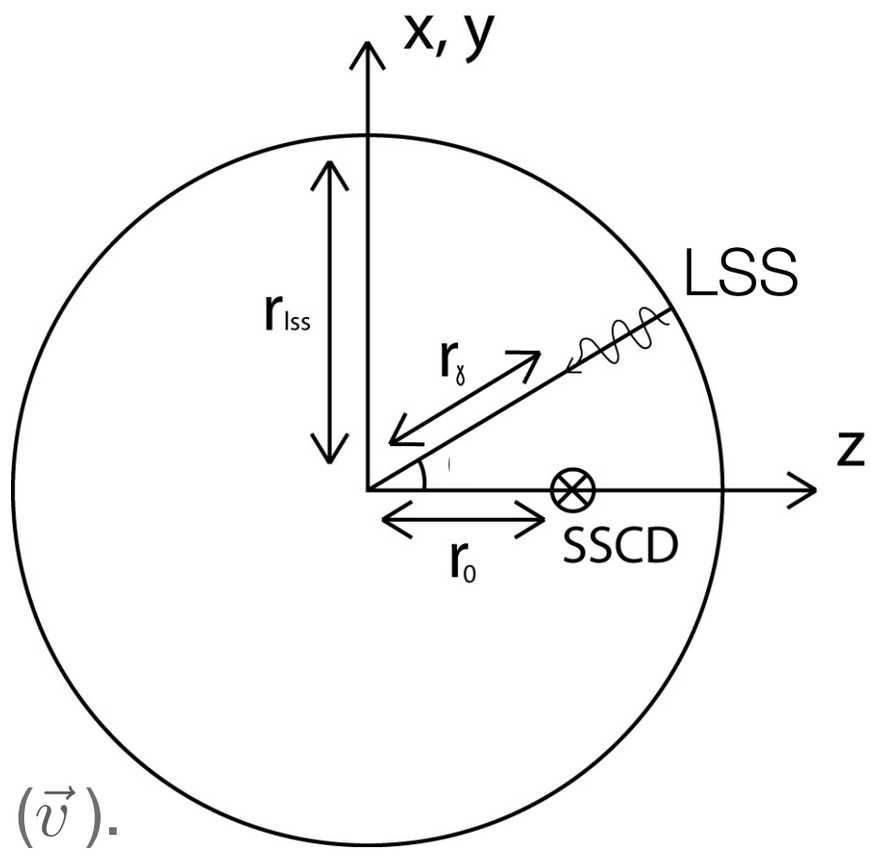

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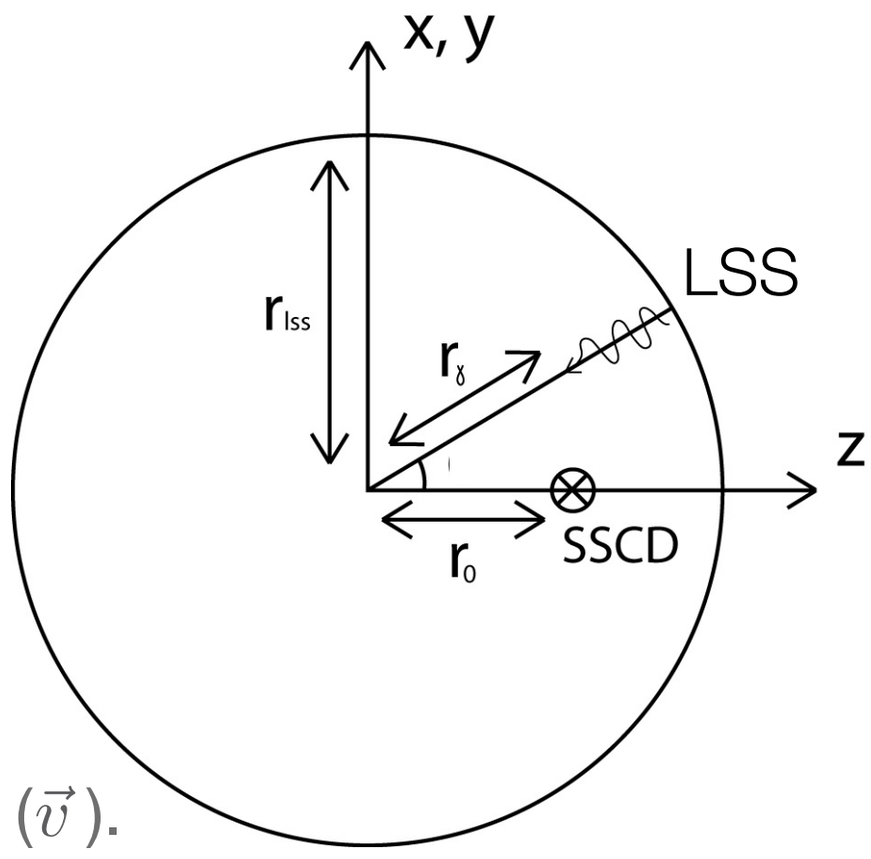

Constraining Parameter Space

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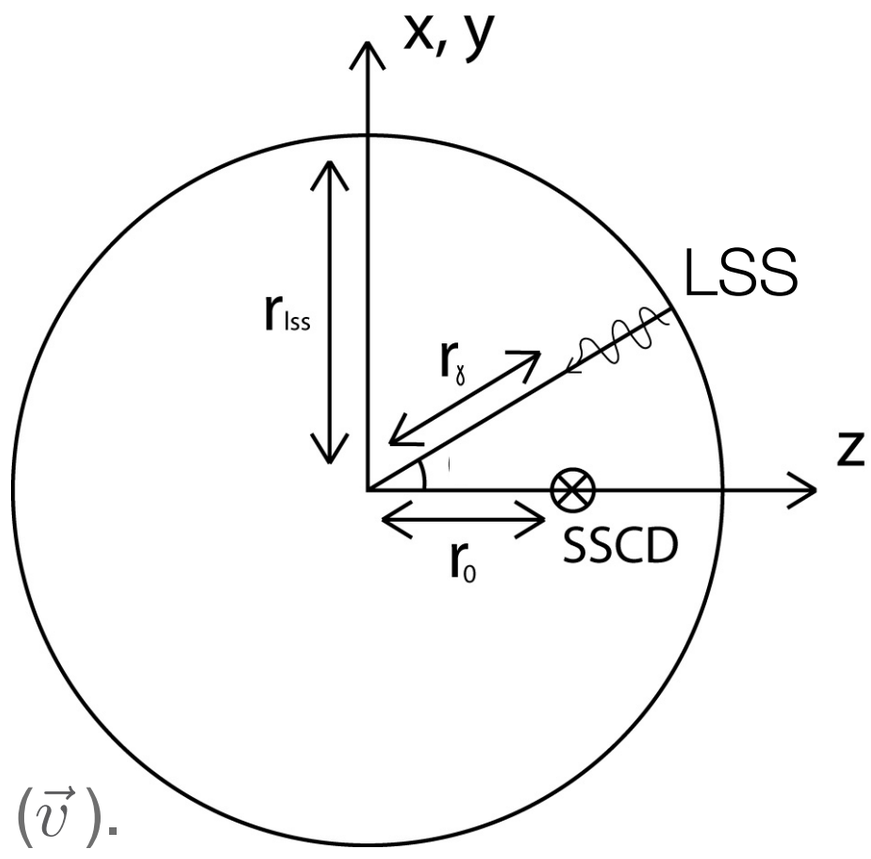
- Fit to data.



Future

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Future

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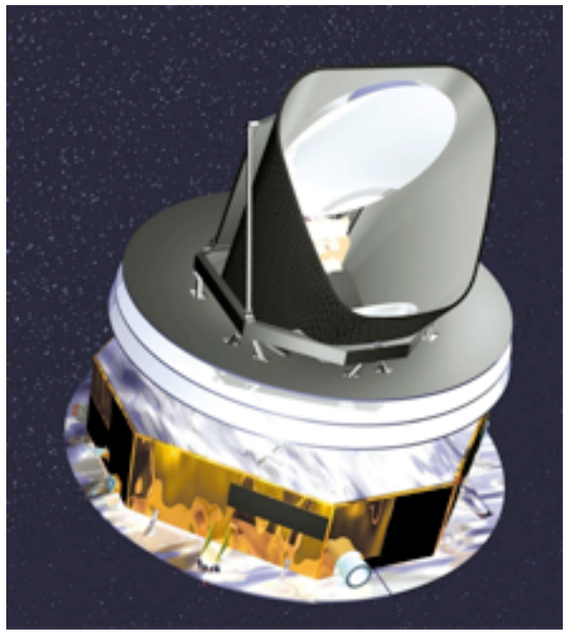
Using new observational data:



Future

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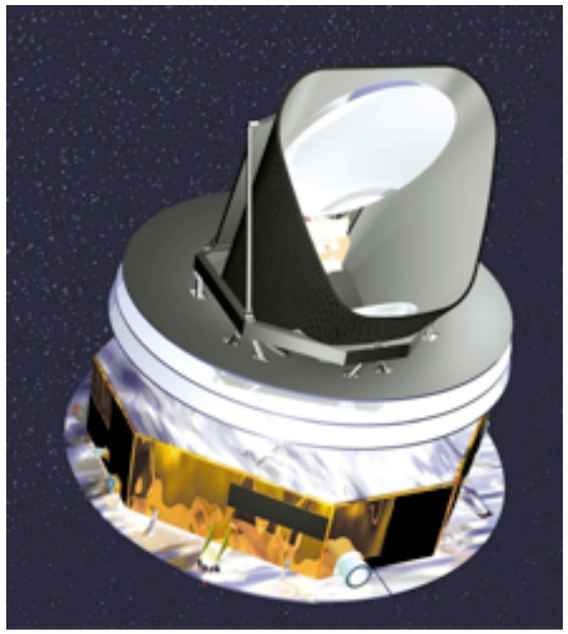
Using new observational data:

- Planck: T_{CMB} Anomalies.



Future

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Using new observational data:

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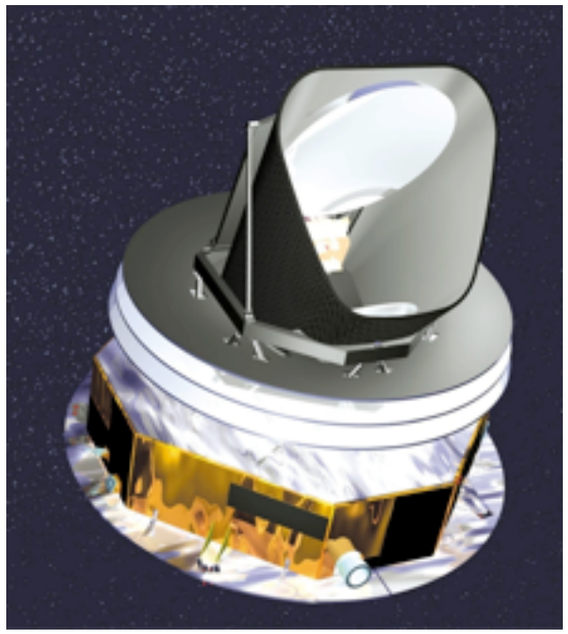

Future

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Using new observational data:

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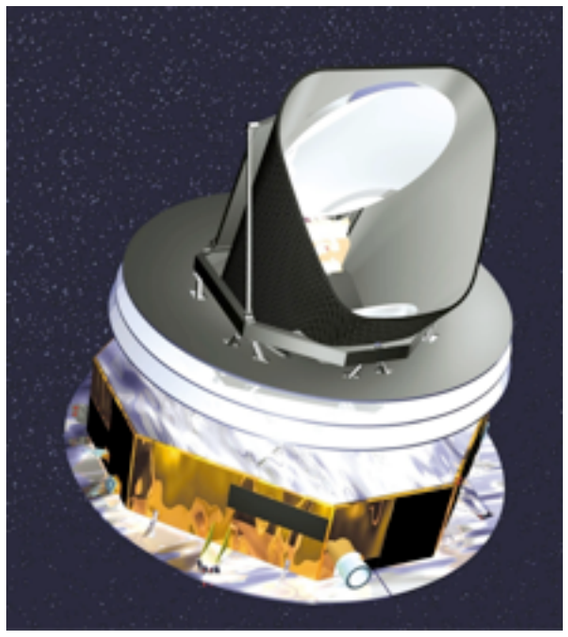

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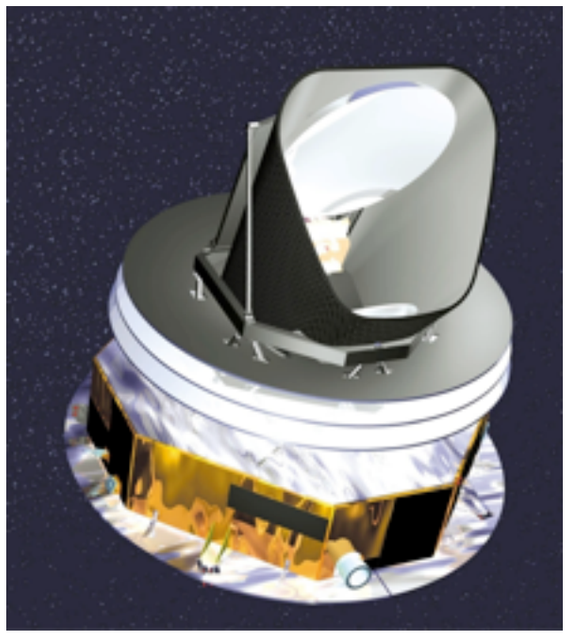

- SNIa: BF converges at high-z?

SCP Supernova Cosmology Project

Takeaway

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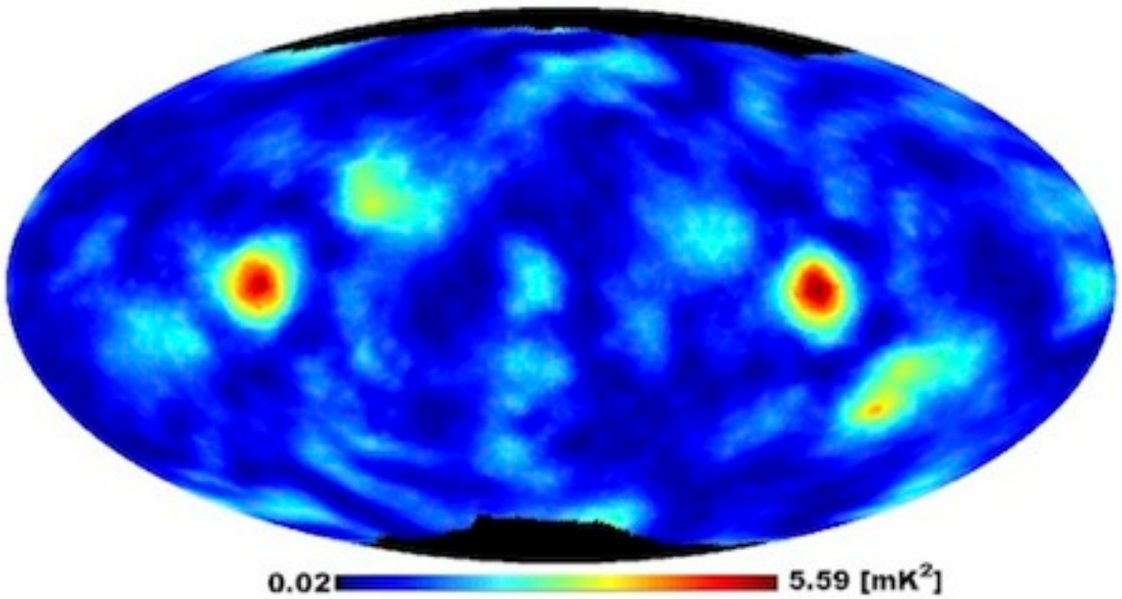

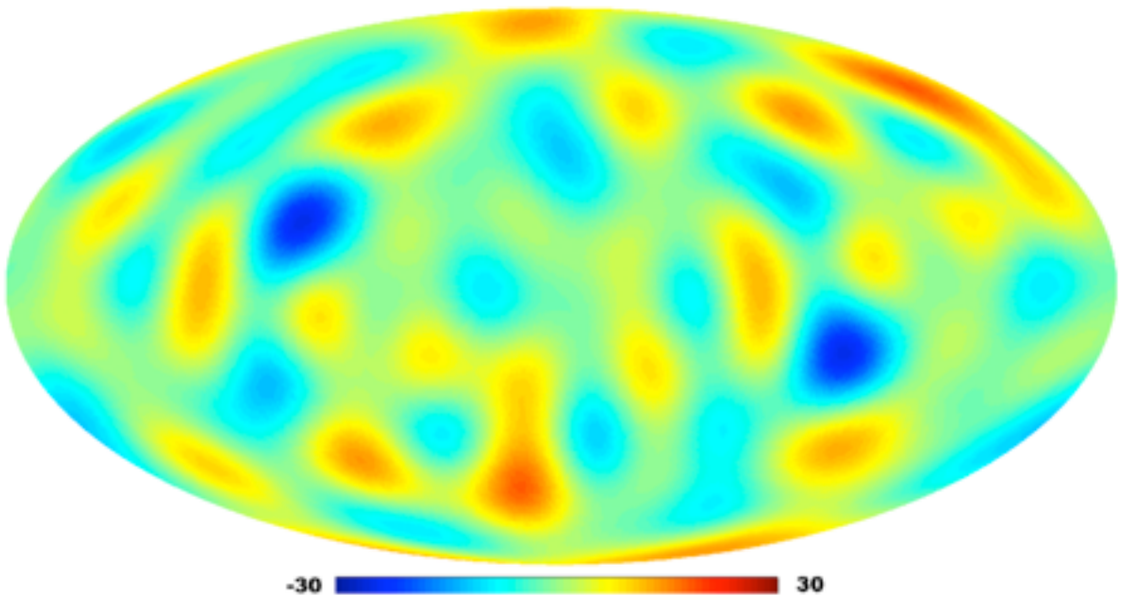

Takeaway

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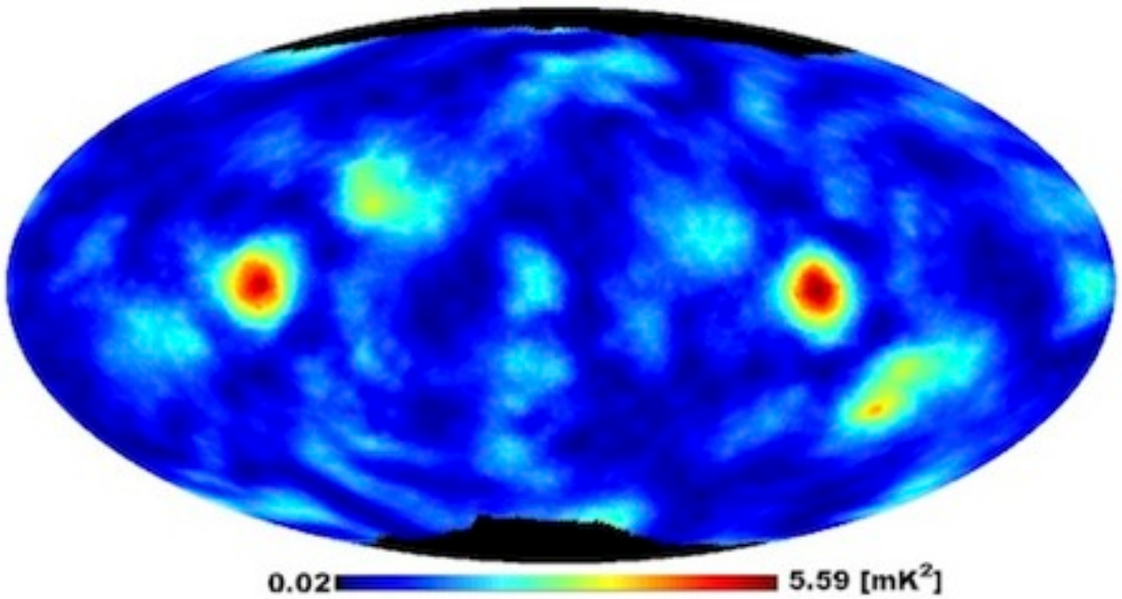
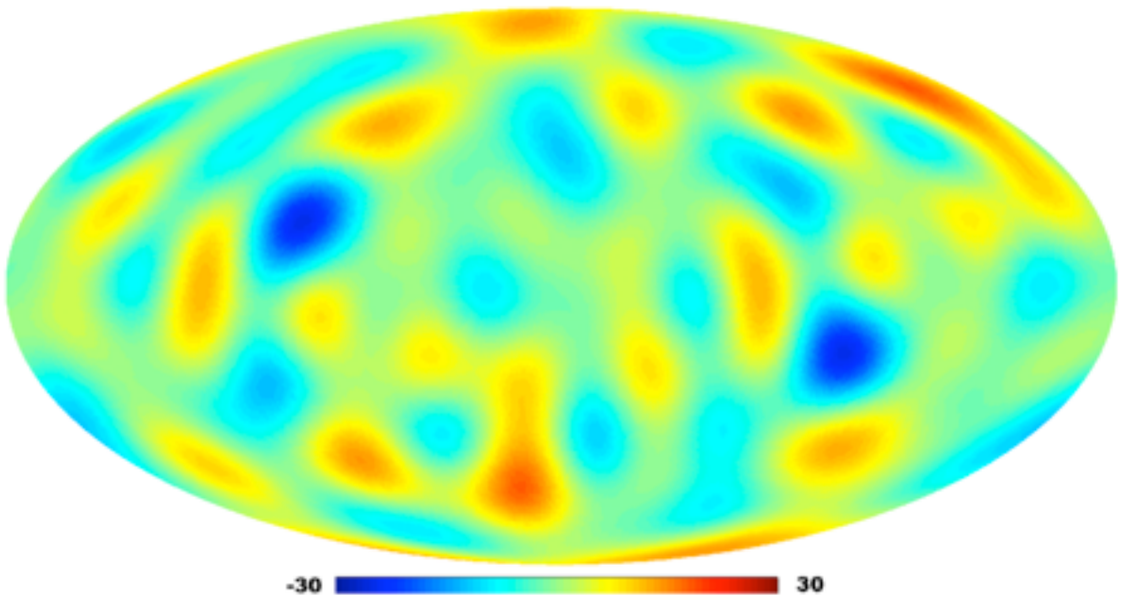
- Phenomenology of pre-inflationary physics: large scale anomalies.





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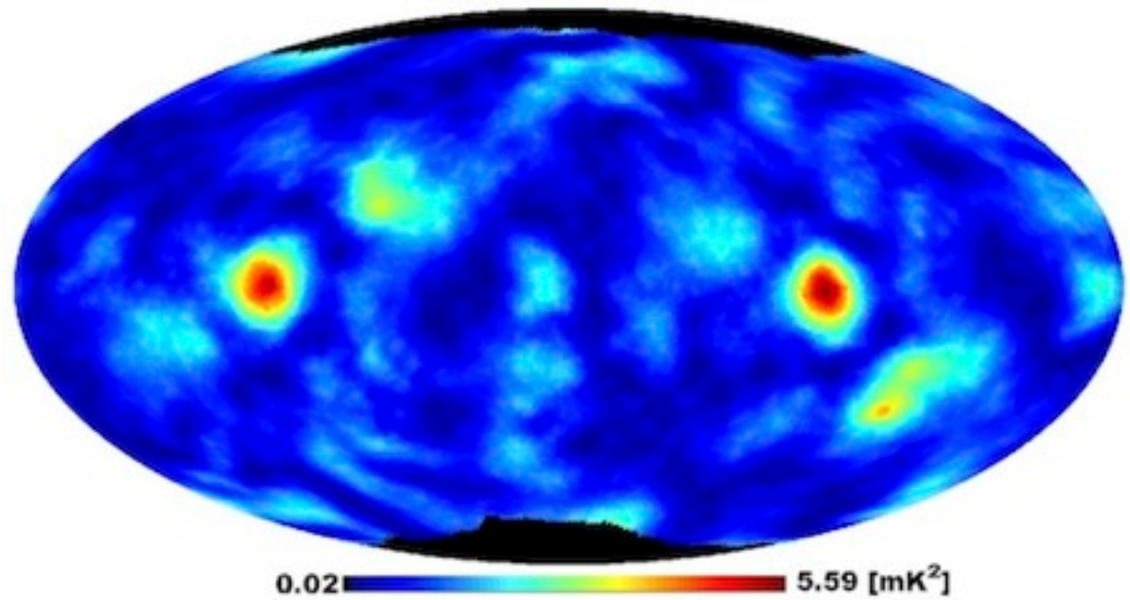

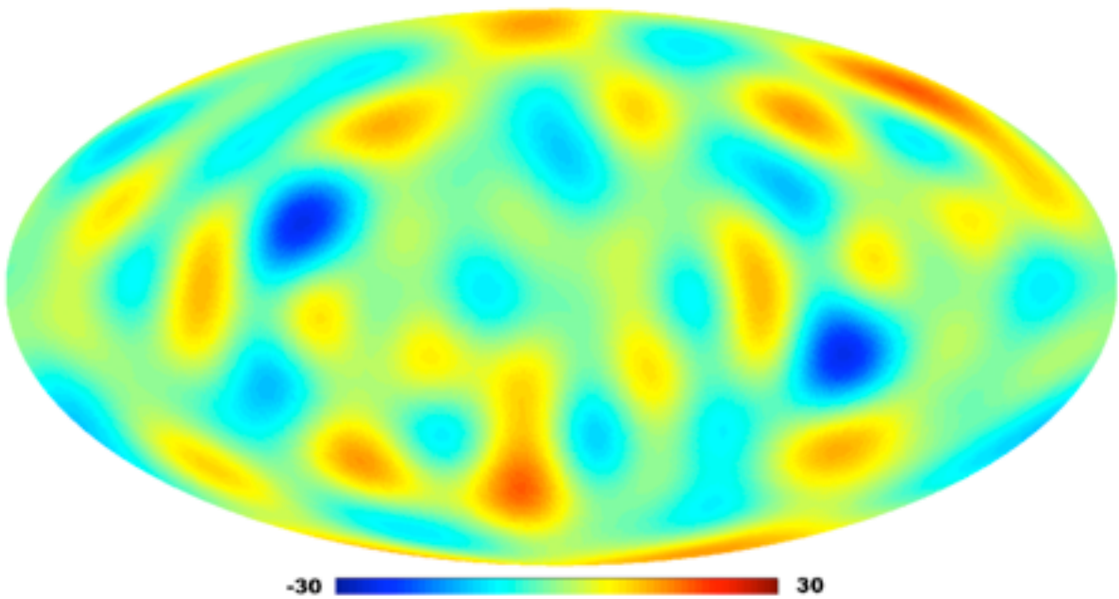

- Bubble Collisions

Takeaway

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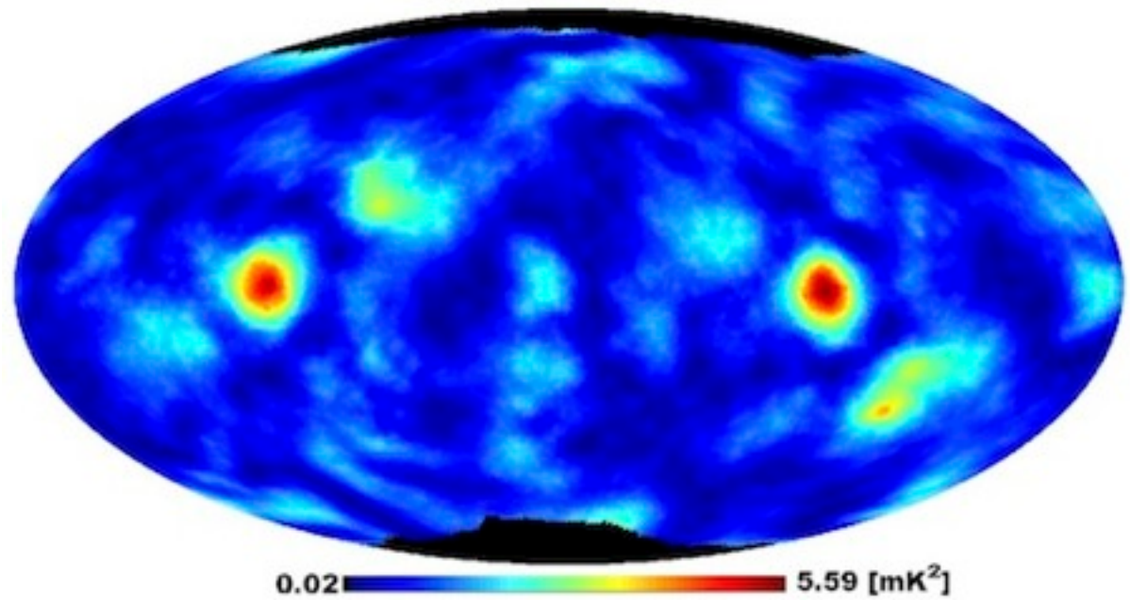

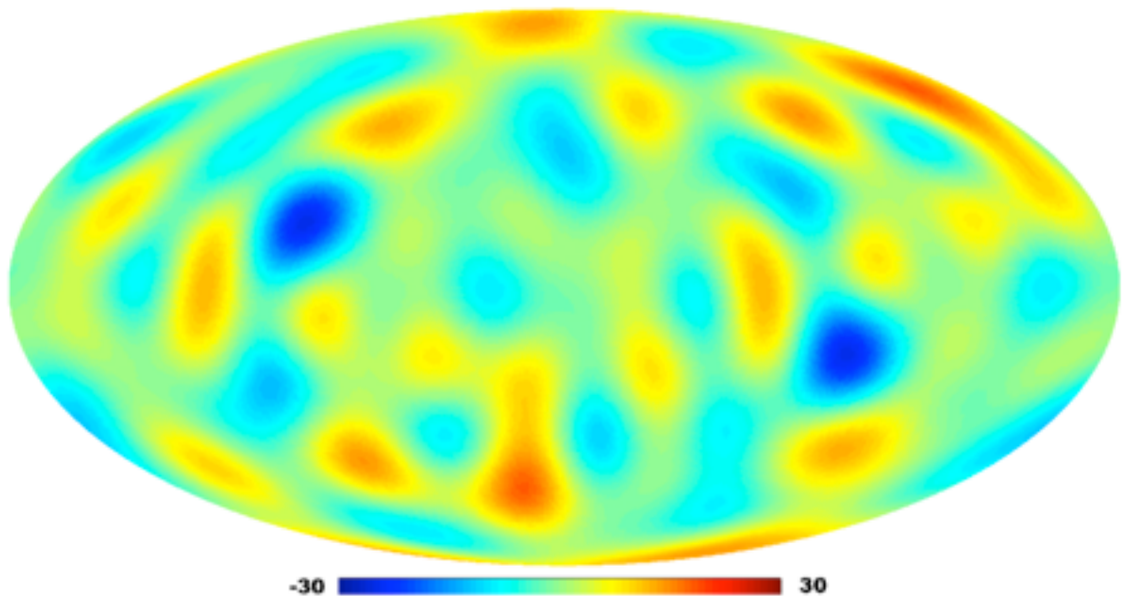

- Bubble Collisions

  Produce rings profile?

Takeaway

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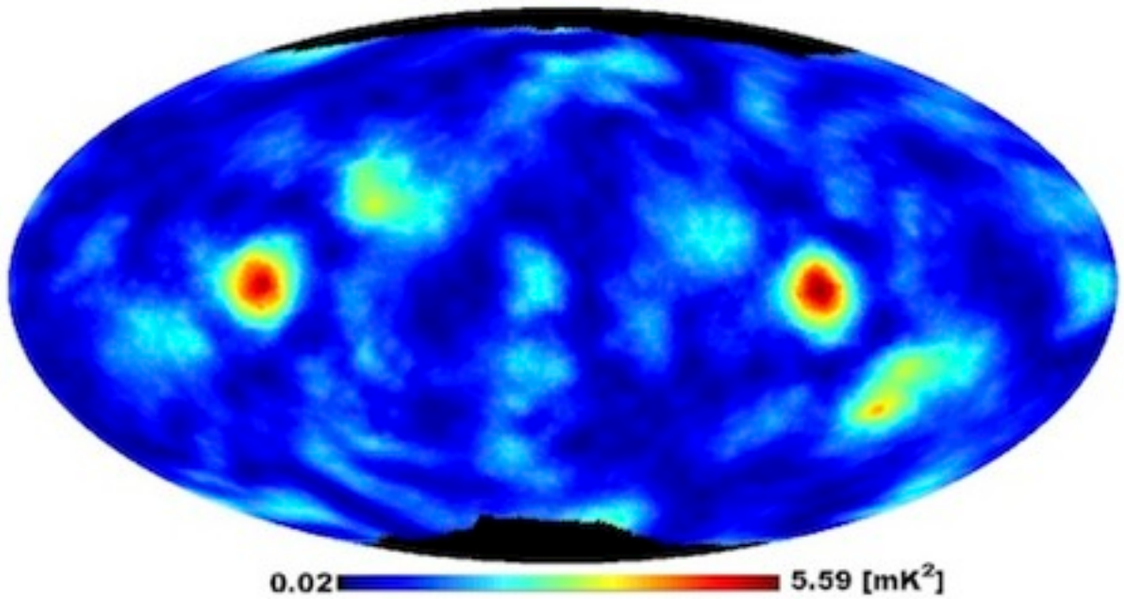

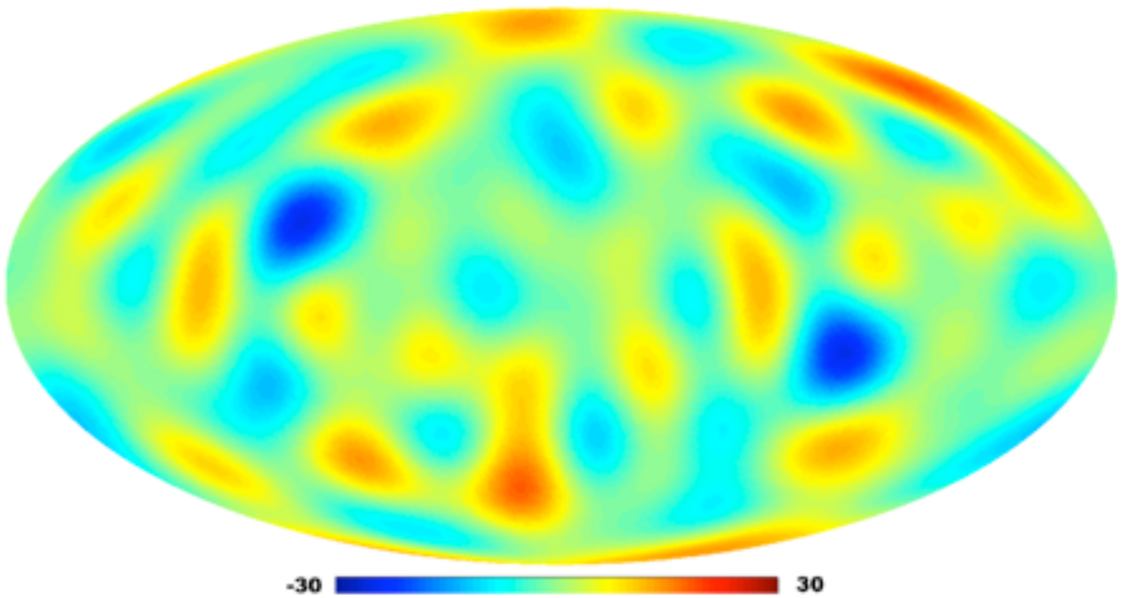

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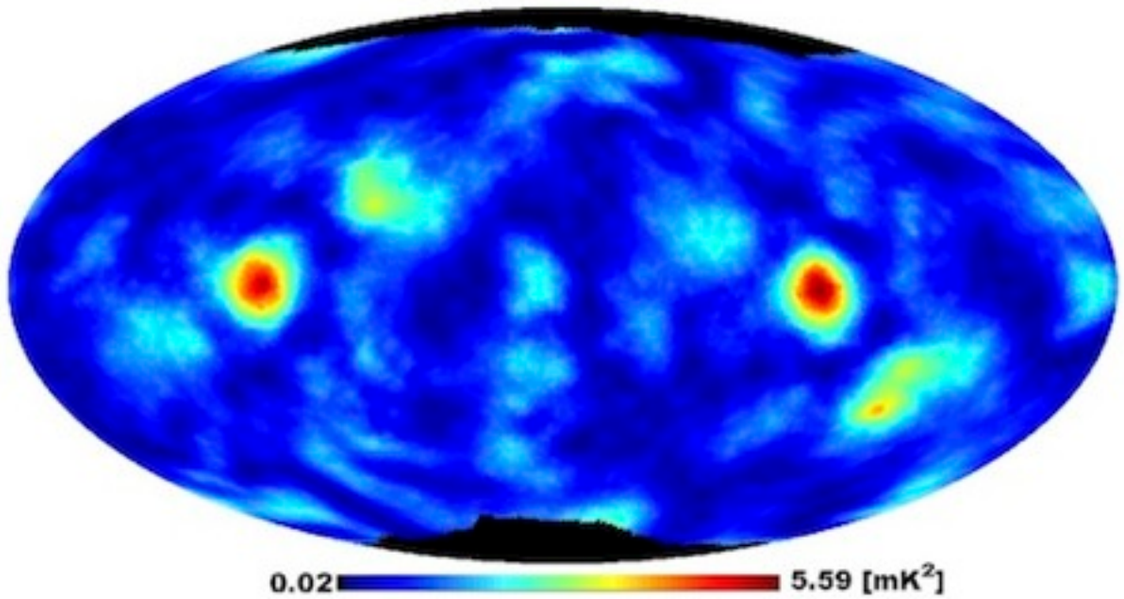

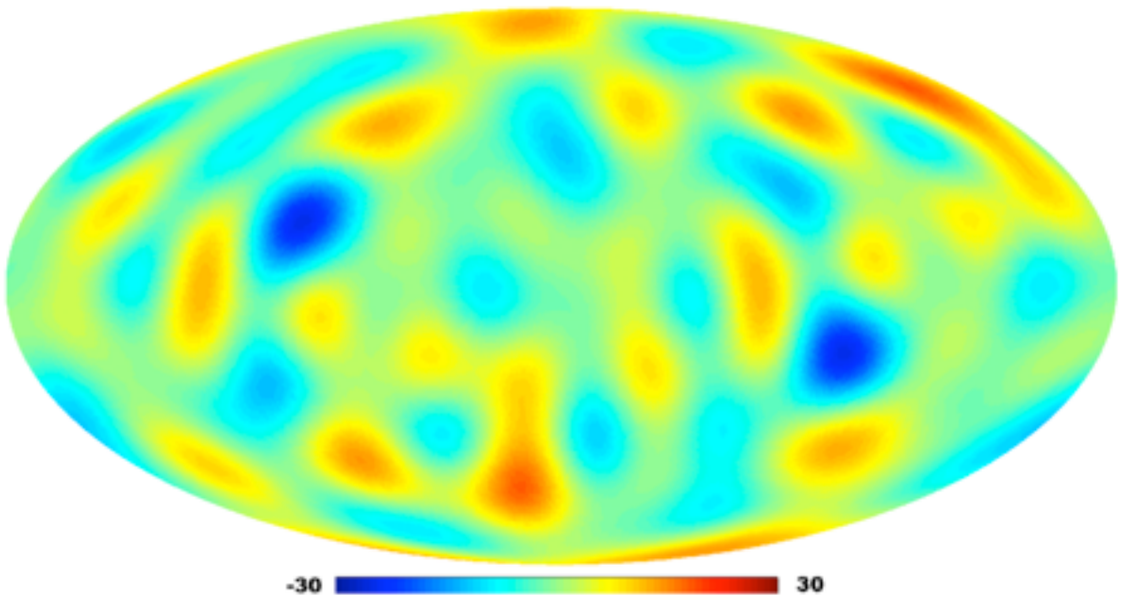

- Bubble Collisions

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  Produce odd parity?

Thank You!

Ely D. Kovetz
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