CMBUBBLES

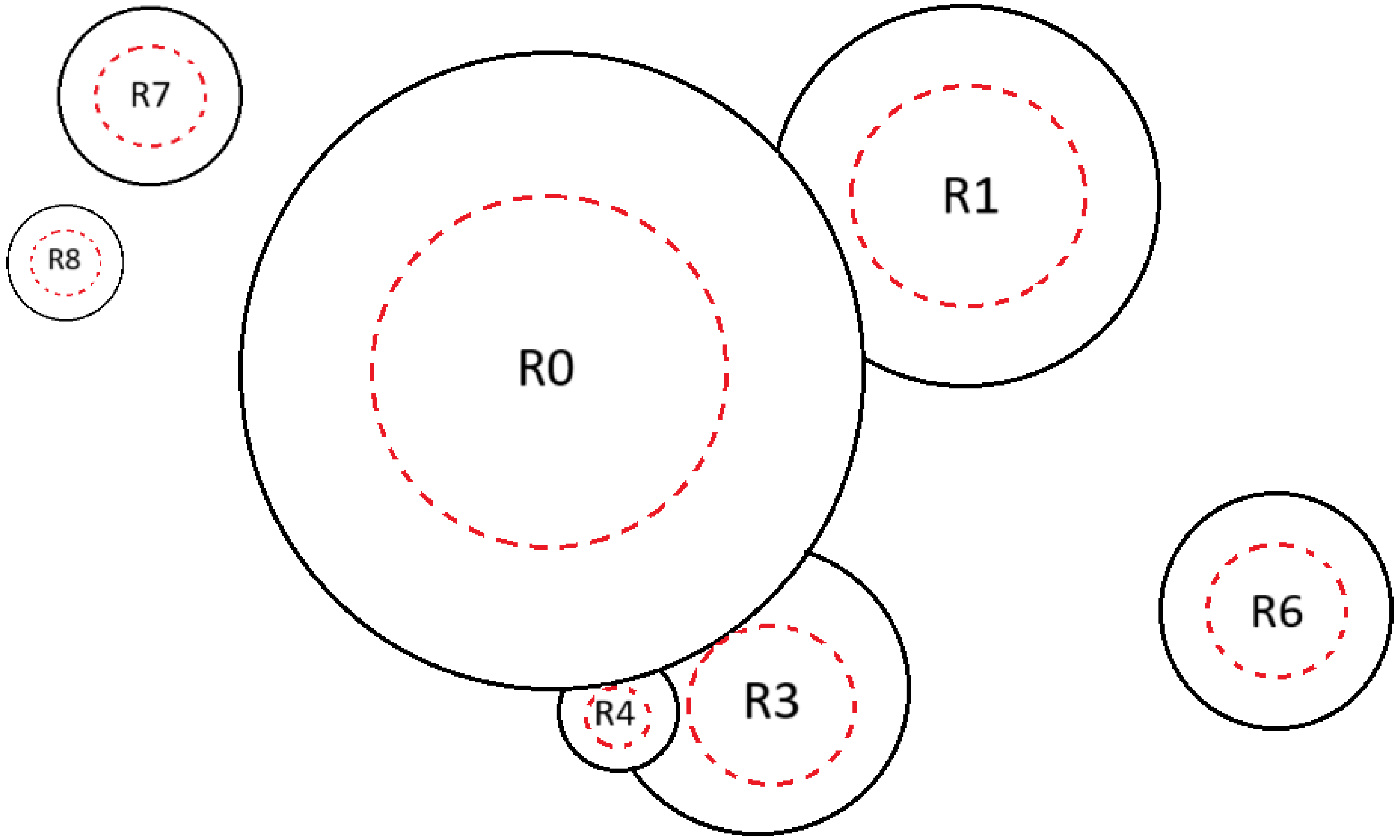
SEARCHING FOR EXISTENCE OF A MULTIVERSE IN PLANCK CMB

Theoretical Cosmology
Jahanvi M (UNSW)

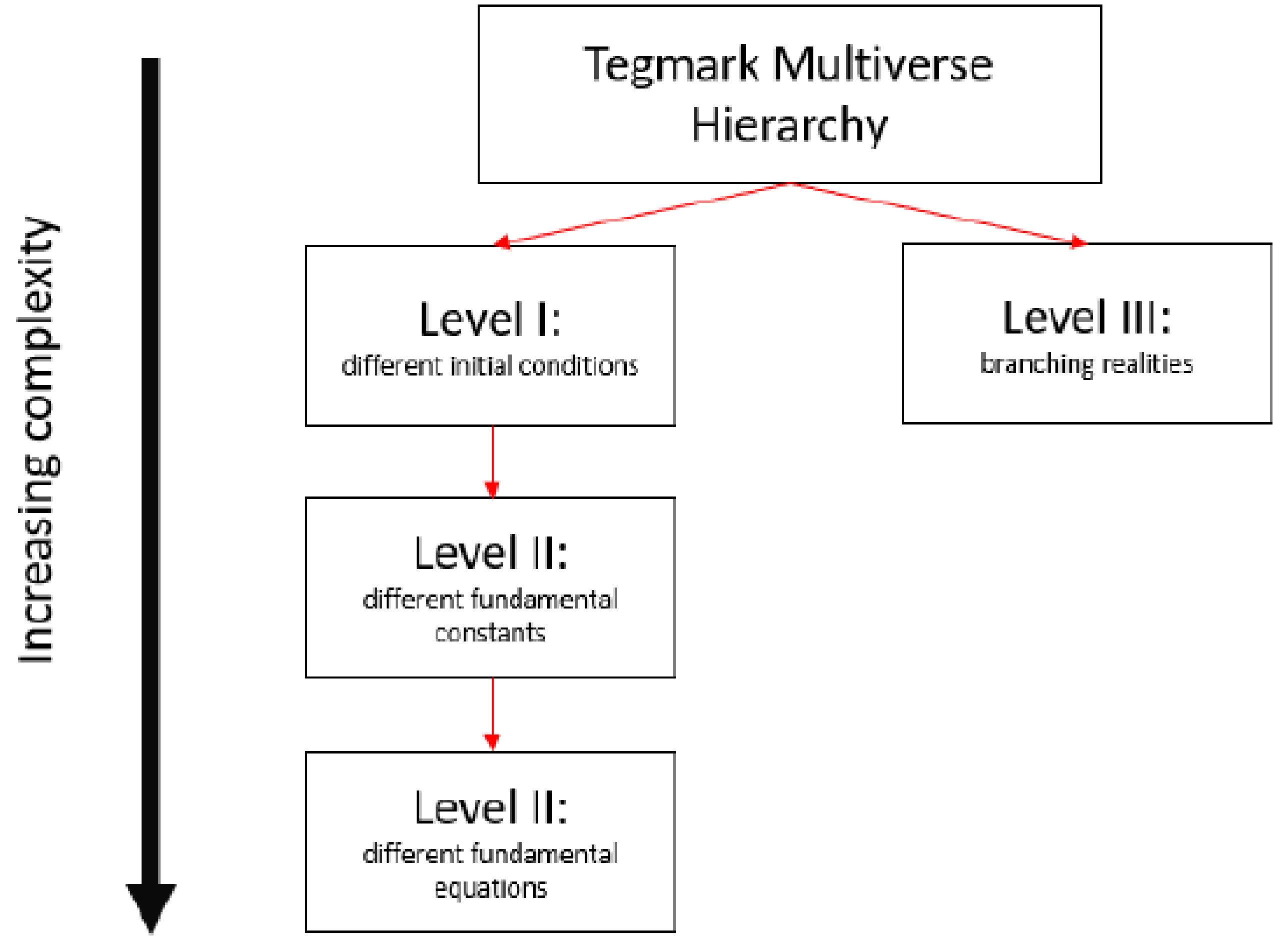
AGENDA

- Motivation
- Theory
- Research
- Outlook

WHAT IS A MULTIVERSE?



"a hypothetical collection of potentially diverse observable universes, each of which would comprise everything that is experimentally accessible by a connected community of observers." (Britannica, 2023)



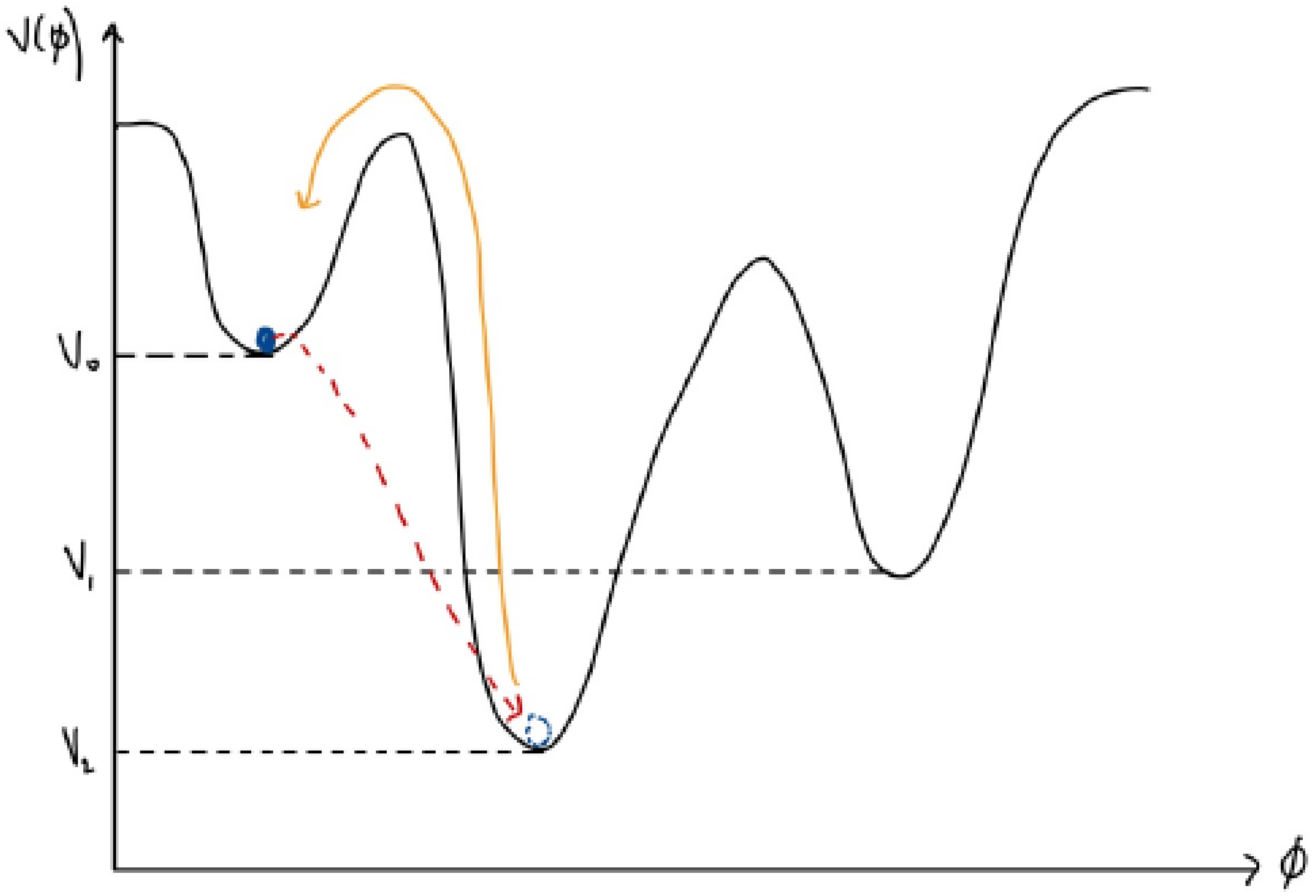
TEGMARK MULTIVERSE

L2 multiverse: multiverse where different observers have same fundamental laws and equations but different fundamental constants.

Inflation models fail to stop -> eternal inflation

Eternal Inflation > Inflation

Inflaton does not decay 'everywhere', only in specific regions



1D Potential Toy Model

BUBBLES?

QFT False Vacuum phenomena

The nucleation of bubbles depends on tunneling from one minimum to another under specific conditions.

The energy lost in these "decays" to contributes to the growth of bubble boundaries.

B-B-BUBBLE COLLISIONS?!

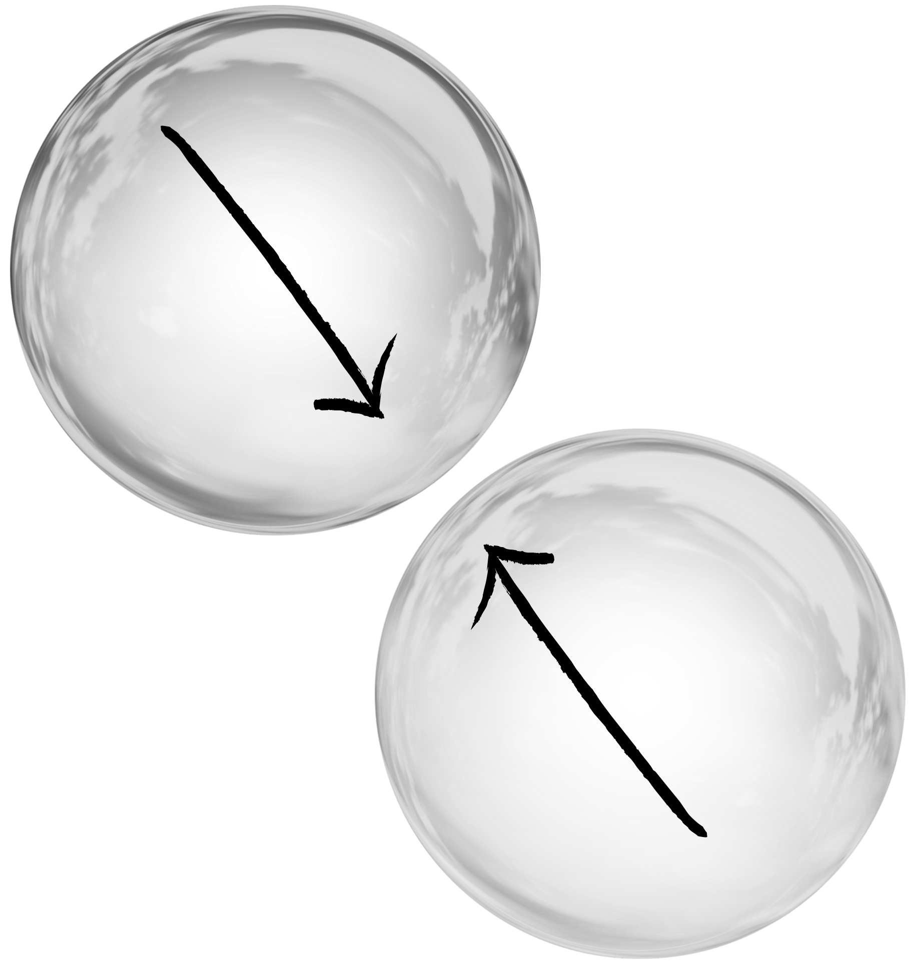
Bubble space expansion and distance

Indirect measurement

Bubbles could "overlap" = collisions

Collisions produce thermal signatures

An imprint in the CMB?



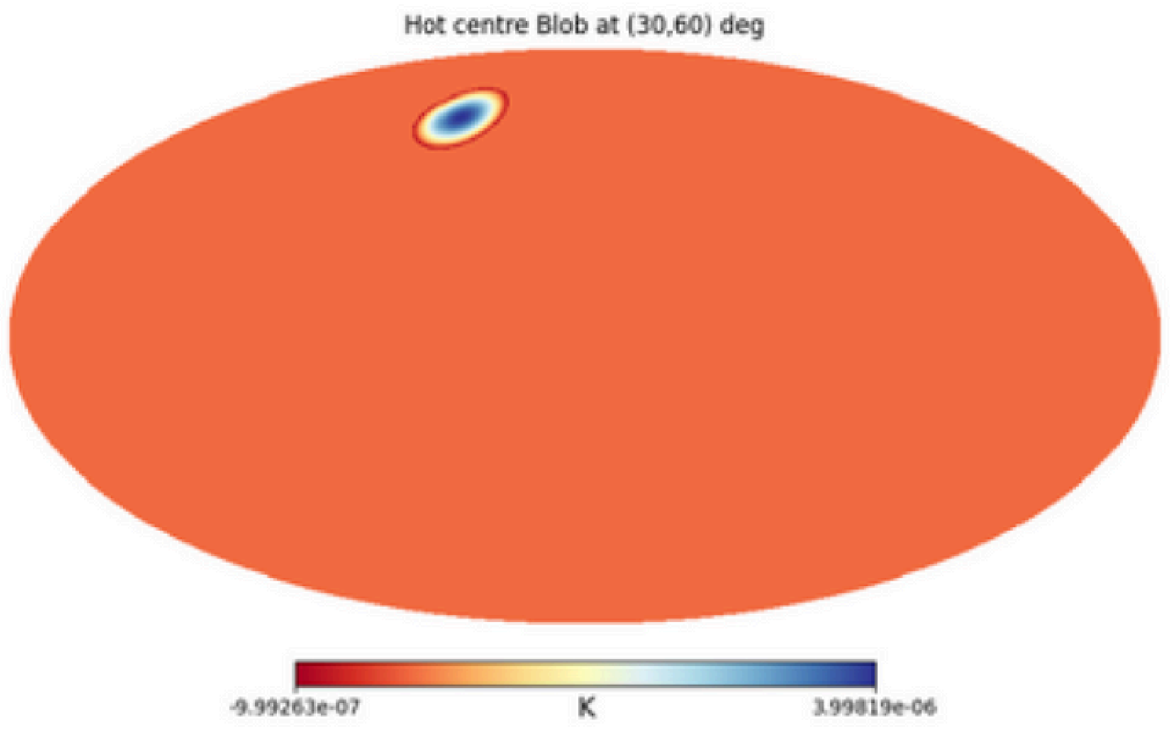
Temperature at bubble boundary

Temperature at bubble centre

Angular distance from bubble centre

$$\frac{\delta T}{T} = \left[\frac{z_{\text{crit}} - z_0 \cos\theta_{\text{crit}}}{1 - \cos\theta_{\text{crit}}} + \frac{z_0 - z_{\text{crit}}}{1 - \cos\theta_{\text{crit}}} \cos\theta \right] \Theta(\theta_{\text{crit}} - \theta)$$

Angular diameter of bubble



IMPRINTS?

Thermal signatures on the CMB

Azimuthal symmetry

Causal boundary: A ring

Long wavelength modulation: CMB temperature anisotropies.

How can we look for these?

BACKGROUNDS

CMB “noise” to signal

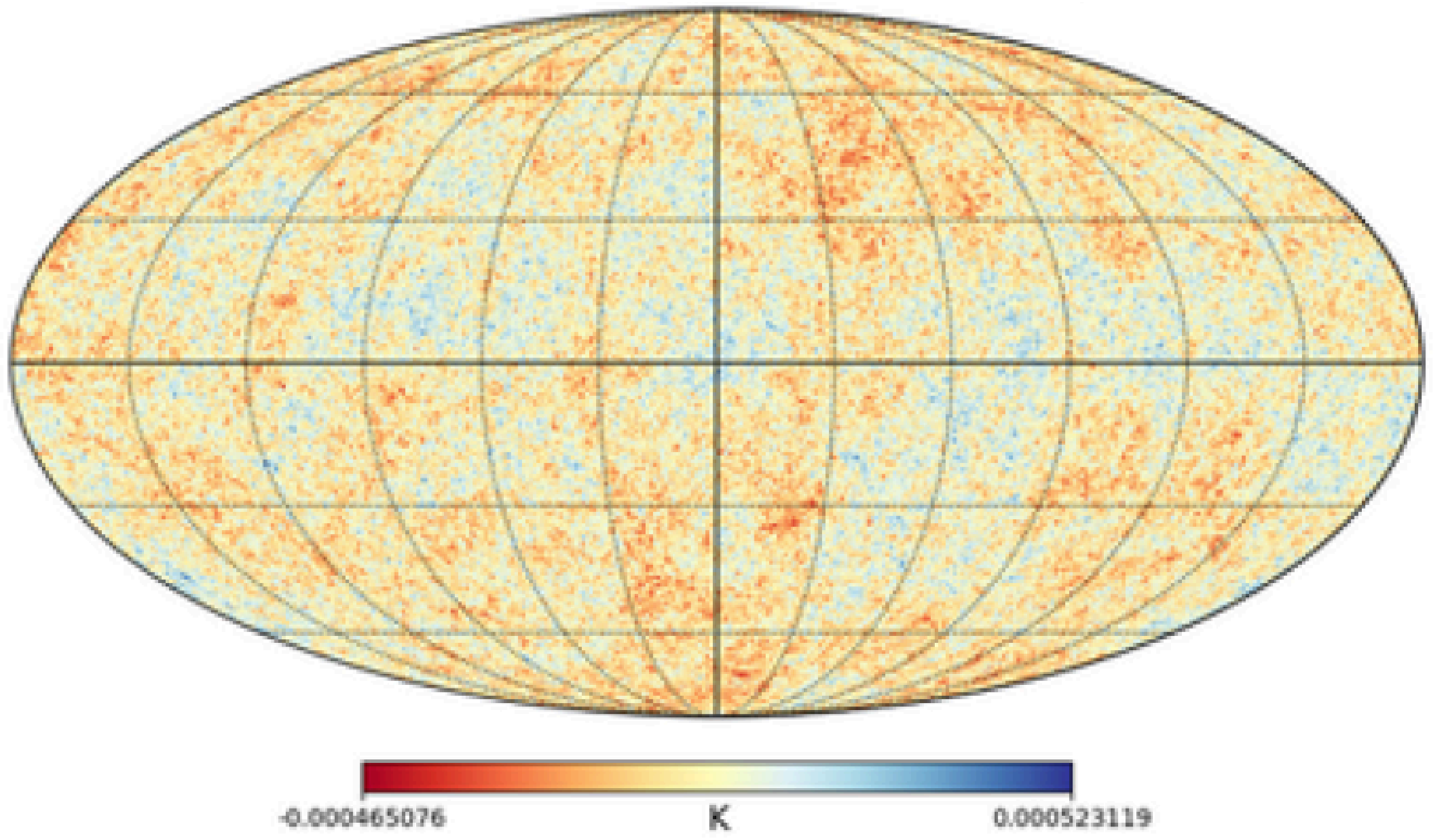
Signal obscured by CMB

Have to be able to detect signatures within this ‘noise’

Our research

Can our pipeline detect a signal in the Planck CMB?

Previous results for WMAP data: Feeney et. al. (2011)

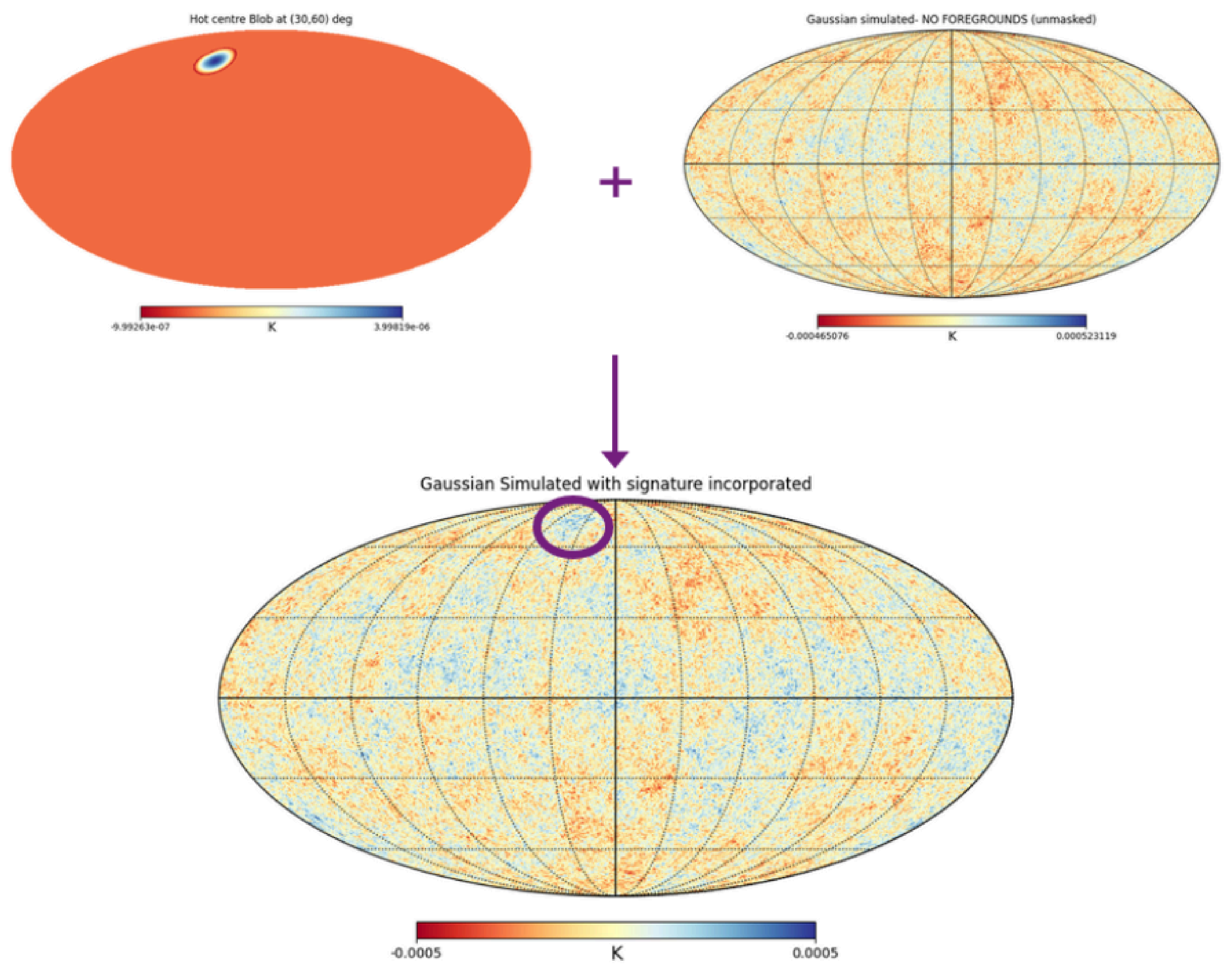


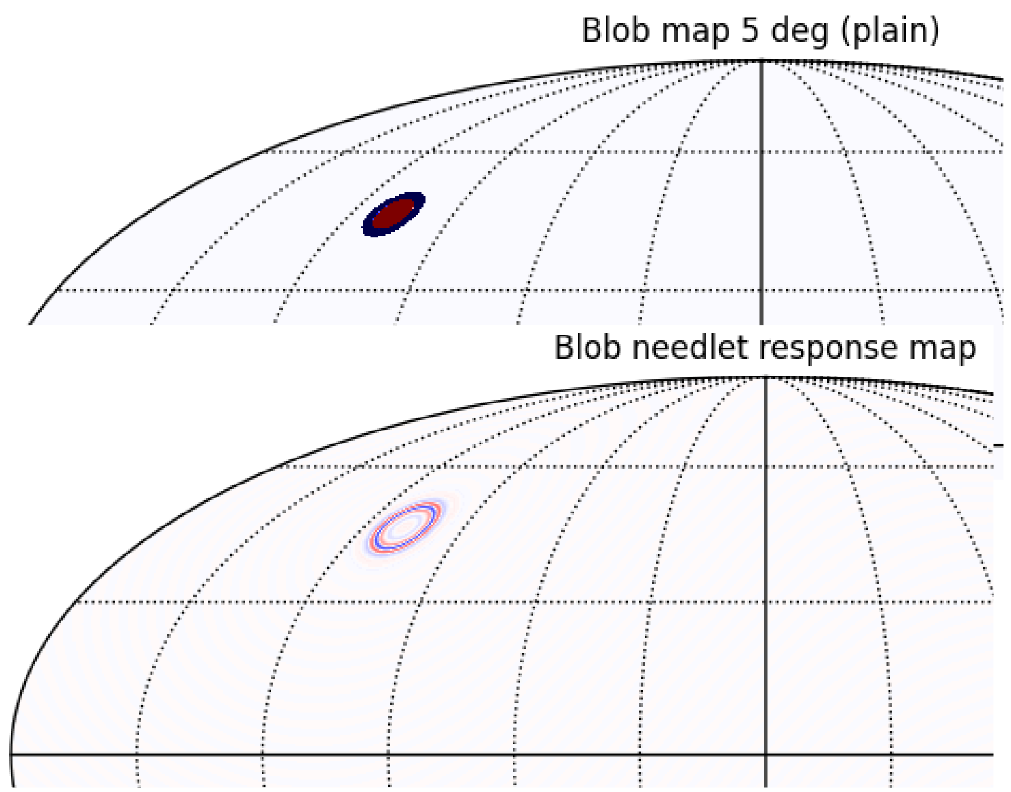
SIMULATIONS

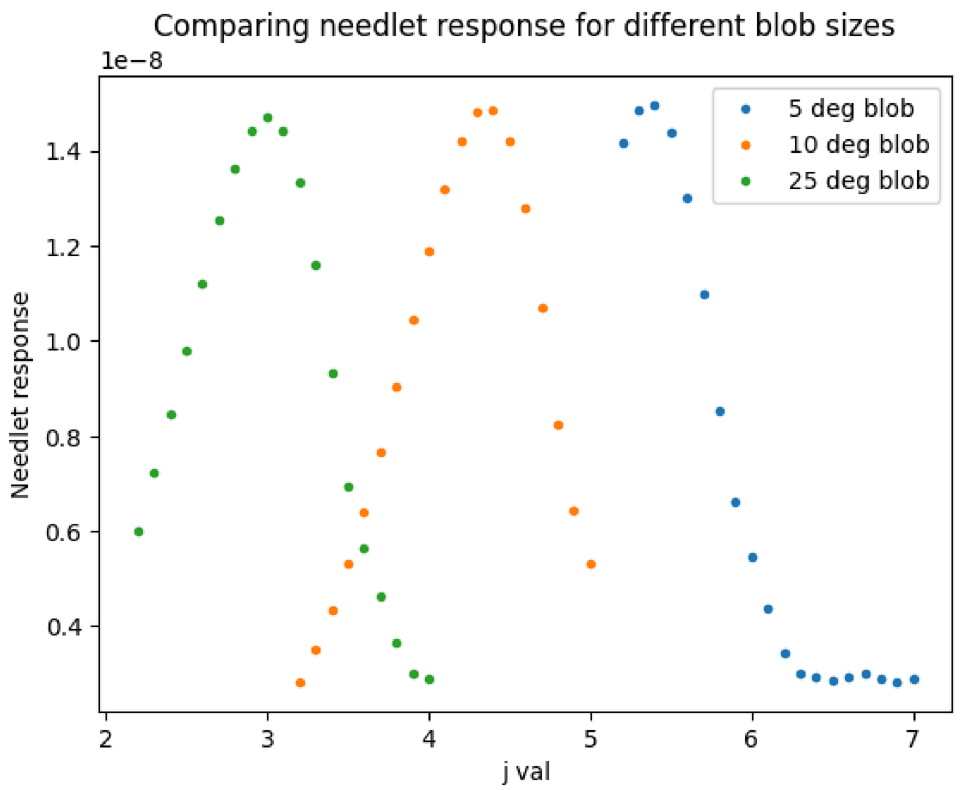
Validity and Sensitivity Testing

Gaussian Simulations: 3000 maps, random seed, ‘backgrounds’ maps.

Blob Signature Simulations: ‘backgrounds’ + signature maps, masked and unmasked regions, size ranges [1,89] degrees and 100 maps each.







NEEDLETS

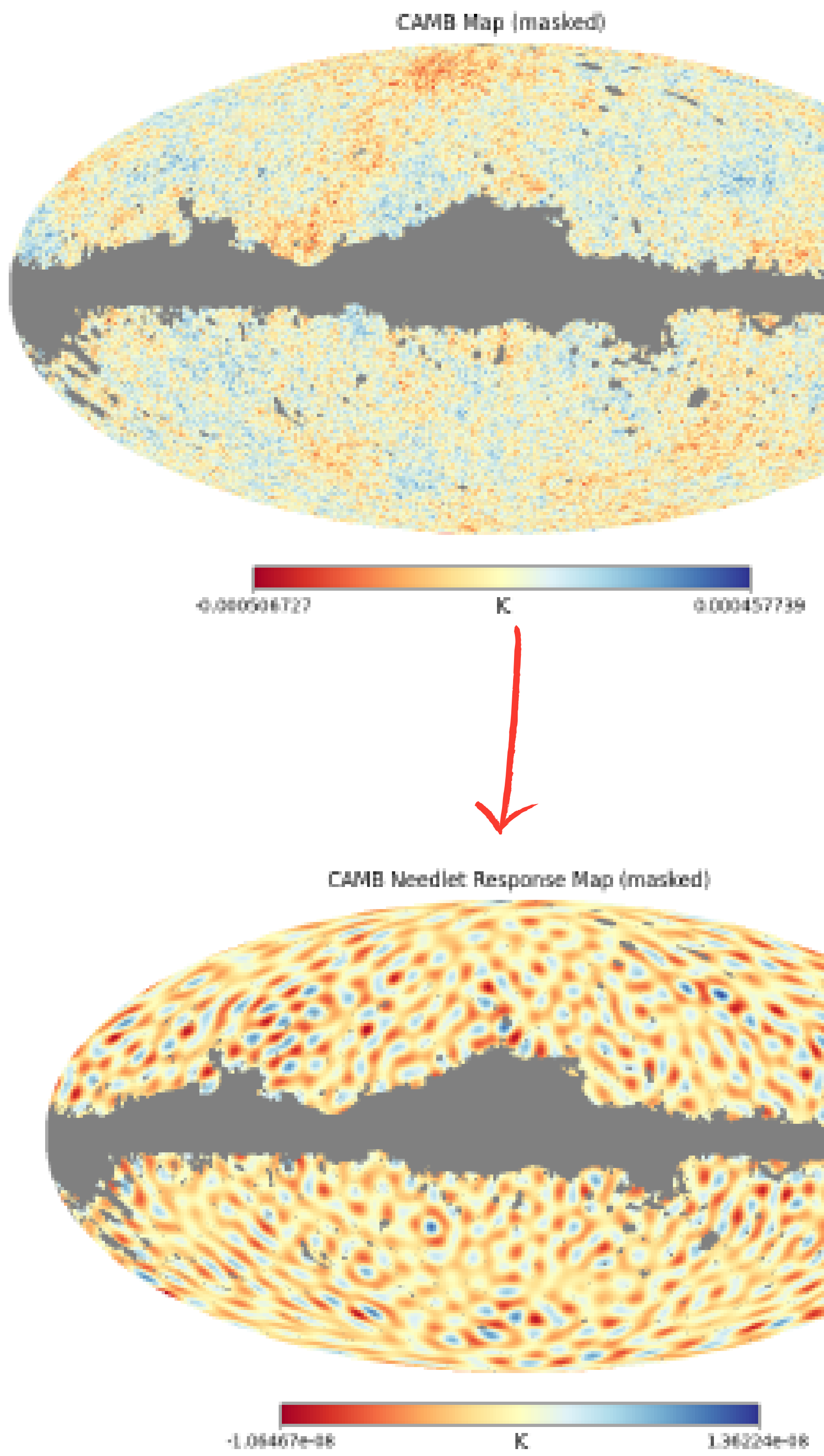
Blob Detection using Needlet filtering

Easier to identify circular profiles

B- parameter: bandwidth parameter, controls the width of each window function in harmonic space.

j- parameter: “frequency” which is related to spatial extent of needlet ([0, inf)).

Need to identify optimal B- and j-values in the Needlet pipeline. Different blob sizes have optimal values.



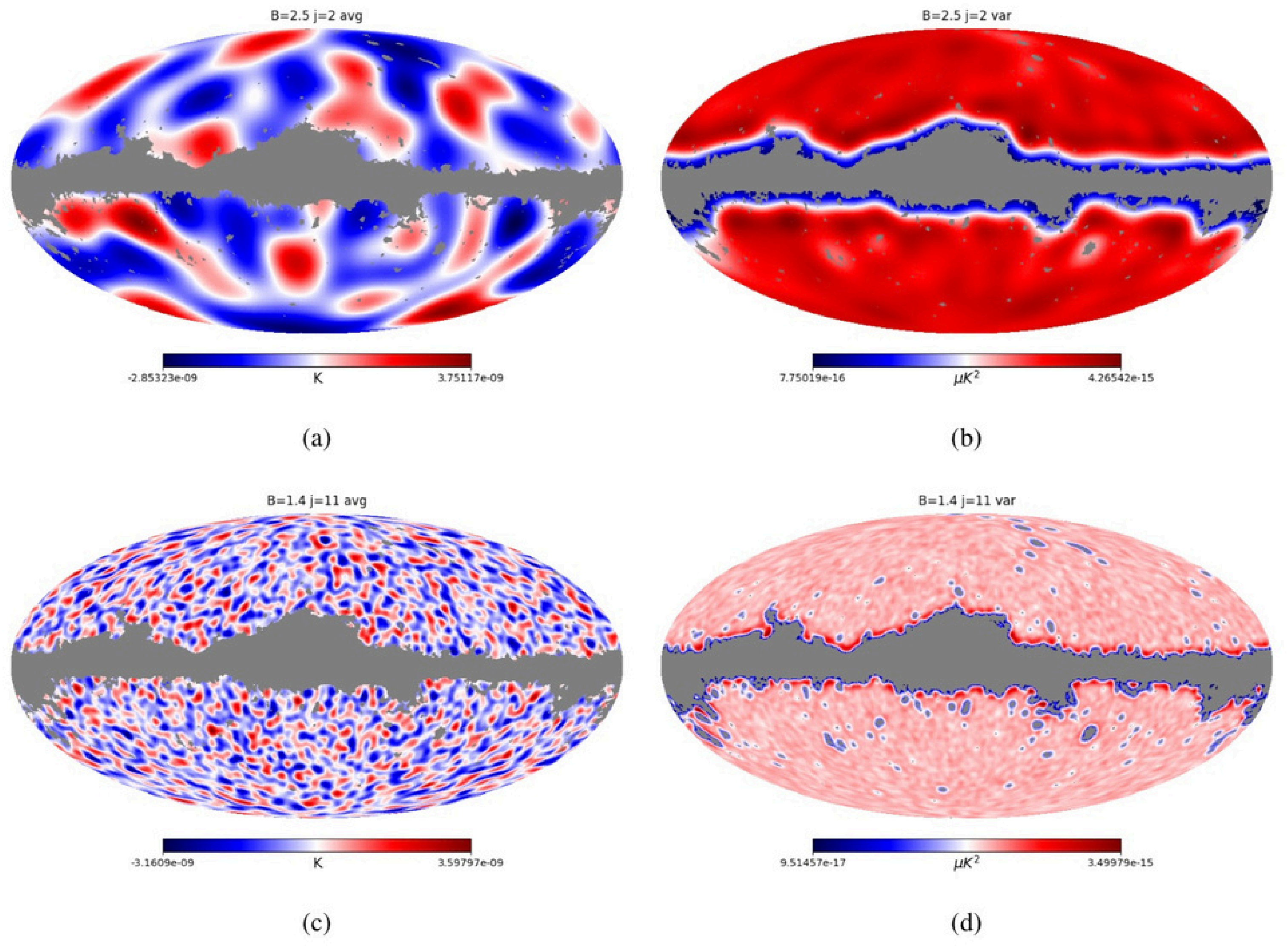
PIPELINE

Blob Detection using Needlet filtering

Generate Lookup tables for parameter values for Needlet analysis.

Average and Variance maps generated for pixel-by-pixel range in the 3000 Gaussian dataset.

SIGNIFICANCE?

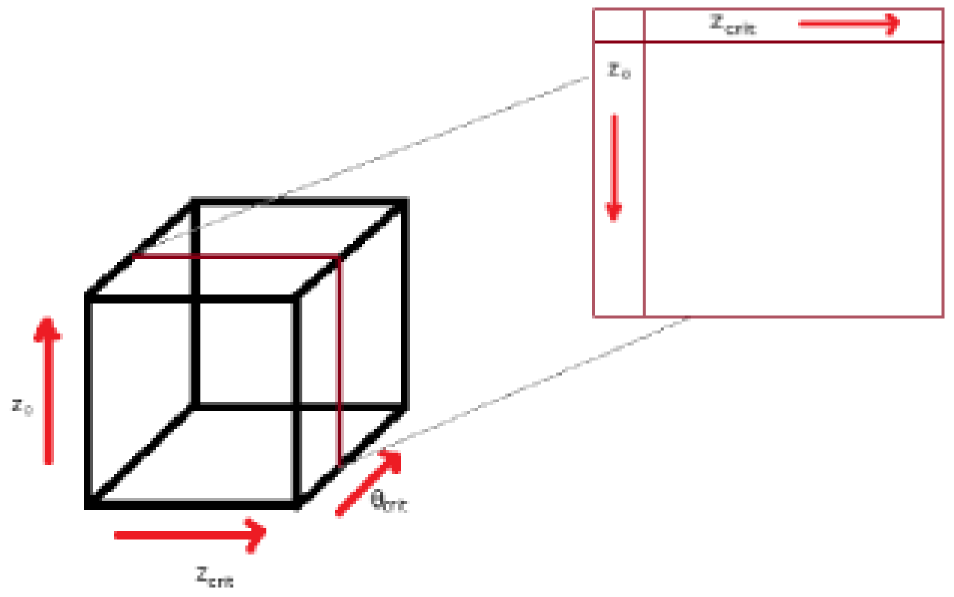


Threshold study using Needlet responses

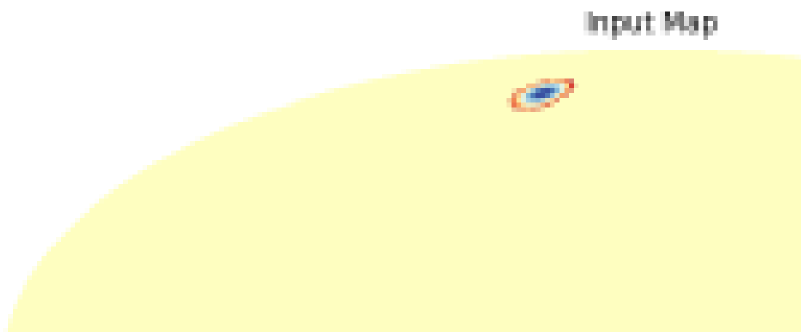
Gaussian dataset tested for each blob size and parameter combination.

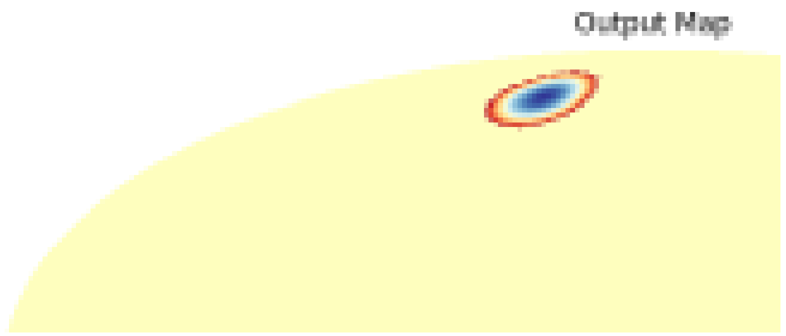
$$S_{jk} = \frac{|\beta_{jk} - \langle \beta_{jk} \rangle_{Gauss,cut}|}{\sqrt{\langle \beta_{jk}^2 \rangle_{Gauss,cut}}}$$

A significant detection is any pixel that passes the threshold value of the 3rd largest needlet response value from the 3000 Gaussian simulations.



Input θ_0	Input ϕ_0	Input θ_{crit}	Input z_0	Input z_{crit}
20	60	5	1.00×10^{-5}	-1.00×10^{-5}
Output θ_0	**Output ϕ_0**	**Output θ_{crit}**	**Output z_0**	**Output z_{crit}**
21.03	58.27	9	5.26×10^{-5}	-5.26×10^{-5}





SSM

Simple Statistical Analysis

Recreating values from needlet responses.

Pipeline takes input map and locates best blob size, and uses that to find the optimal blob center and boundary values.

$$\frac{\delta T}{T} = \left[\frac{z_{\rm crit} - z_0 \cos\theta_{\rm crit}}{1-\cos\theta_{\rm crit}} + \frac{z_0 - z_{\rm crit}}{1-\cos\theta_{\rm crit}} \cos\theta\right] \Theta(\theta_{\rm crit} - \theta)$$

Simple chi-squared model run onto input parameters, compared to pipeline output parameters.

Lower chi-squared value = better model fit.

$$\chi^2 = \sum_{allpixels} \frac{(\Gamma_{map} - \Gamma_{theory})^2}{\sigma^2_{temp}}$$

PLANCK RESULTS

14 features identified, CMB Cold Spot Anomaly... spotted

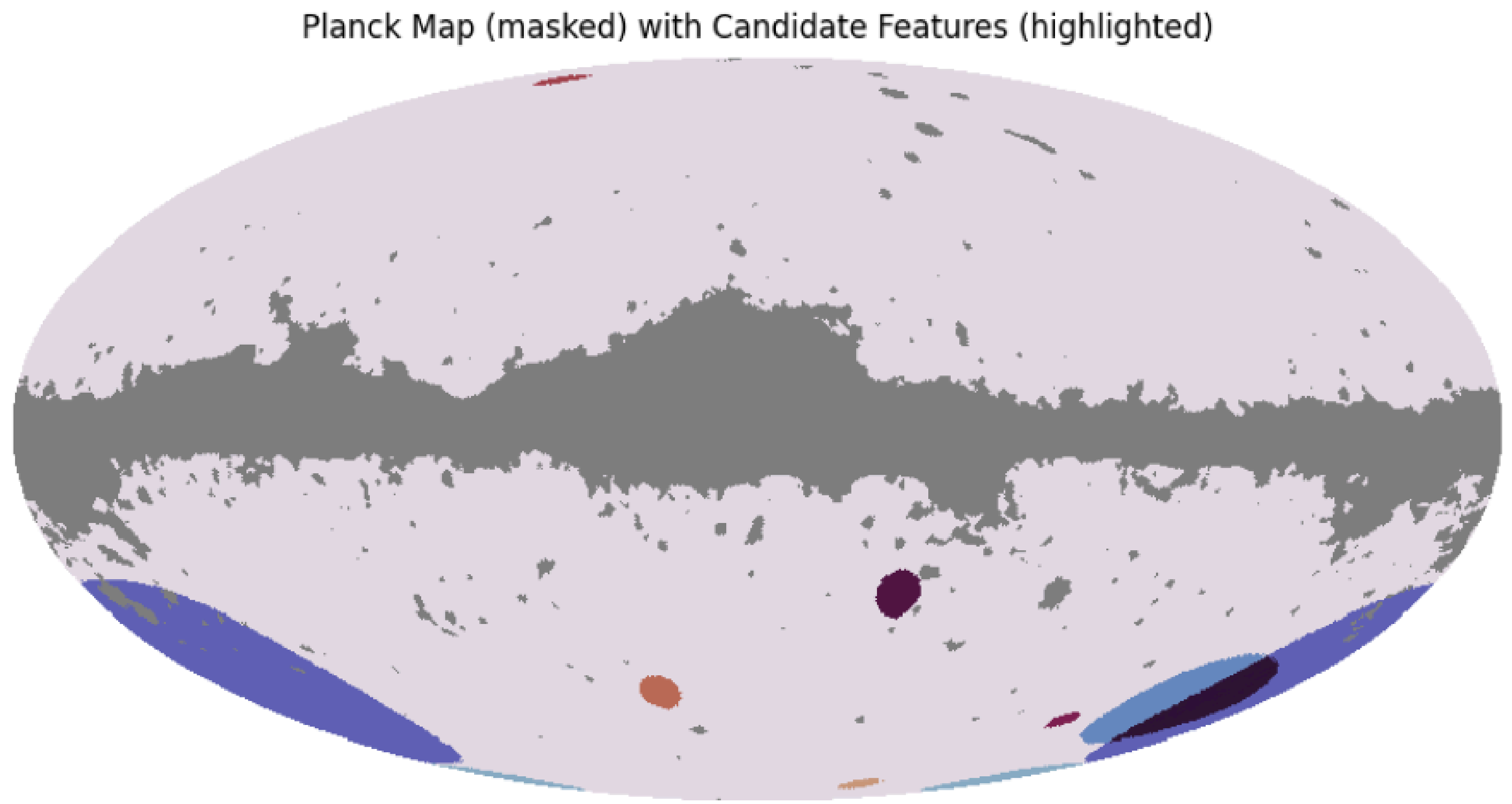
No features pass significance thresholds as per our requirements.

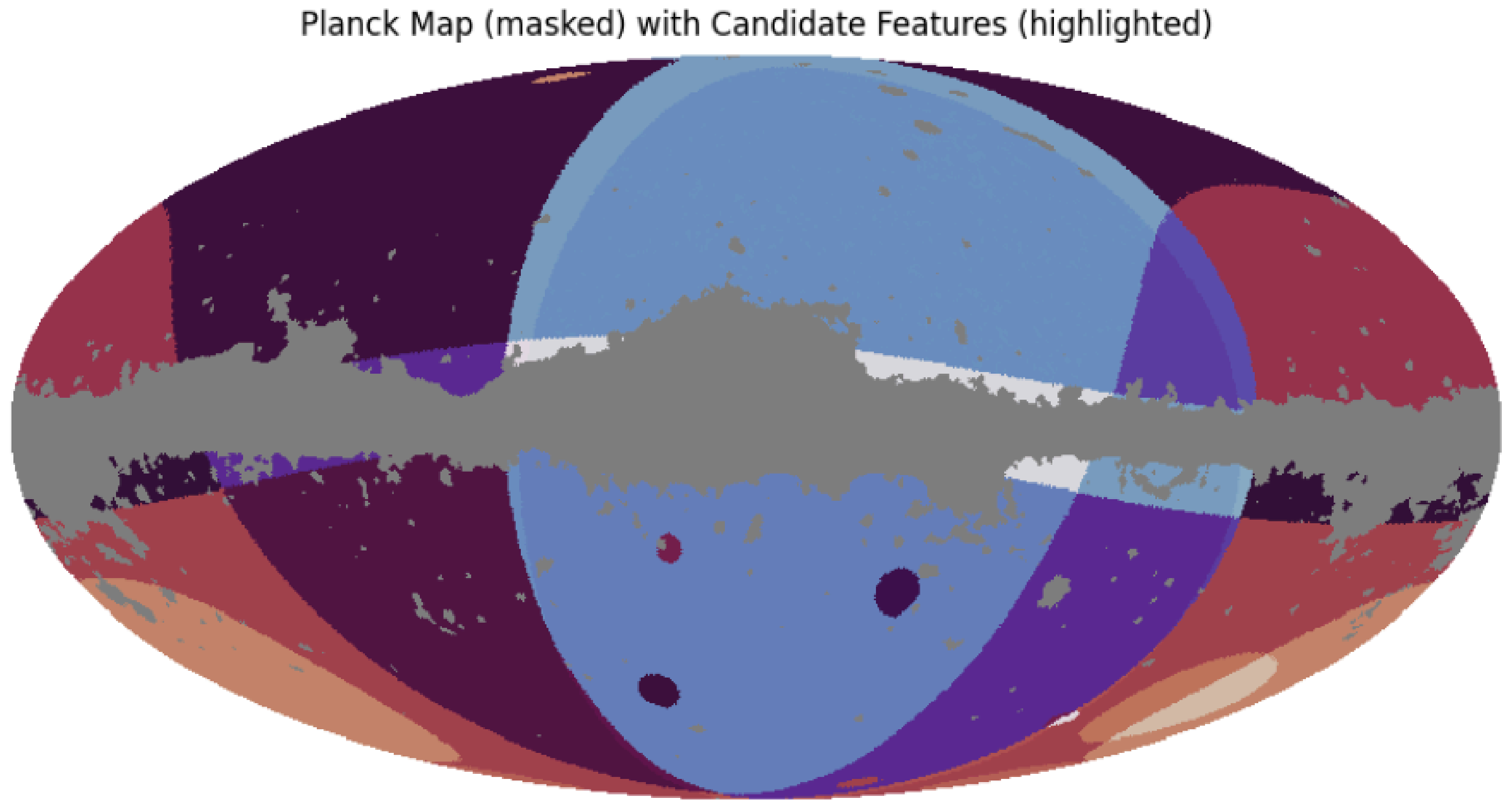
Theoretical limitations

Uncertainty in Blob profile

Significance truncation to 4 sig. figs.

Uncertainty in model outputs





OUTLOOK

Refining detection algorithm

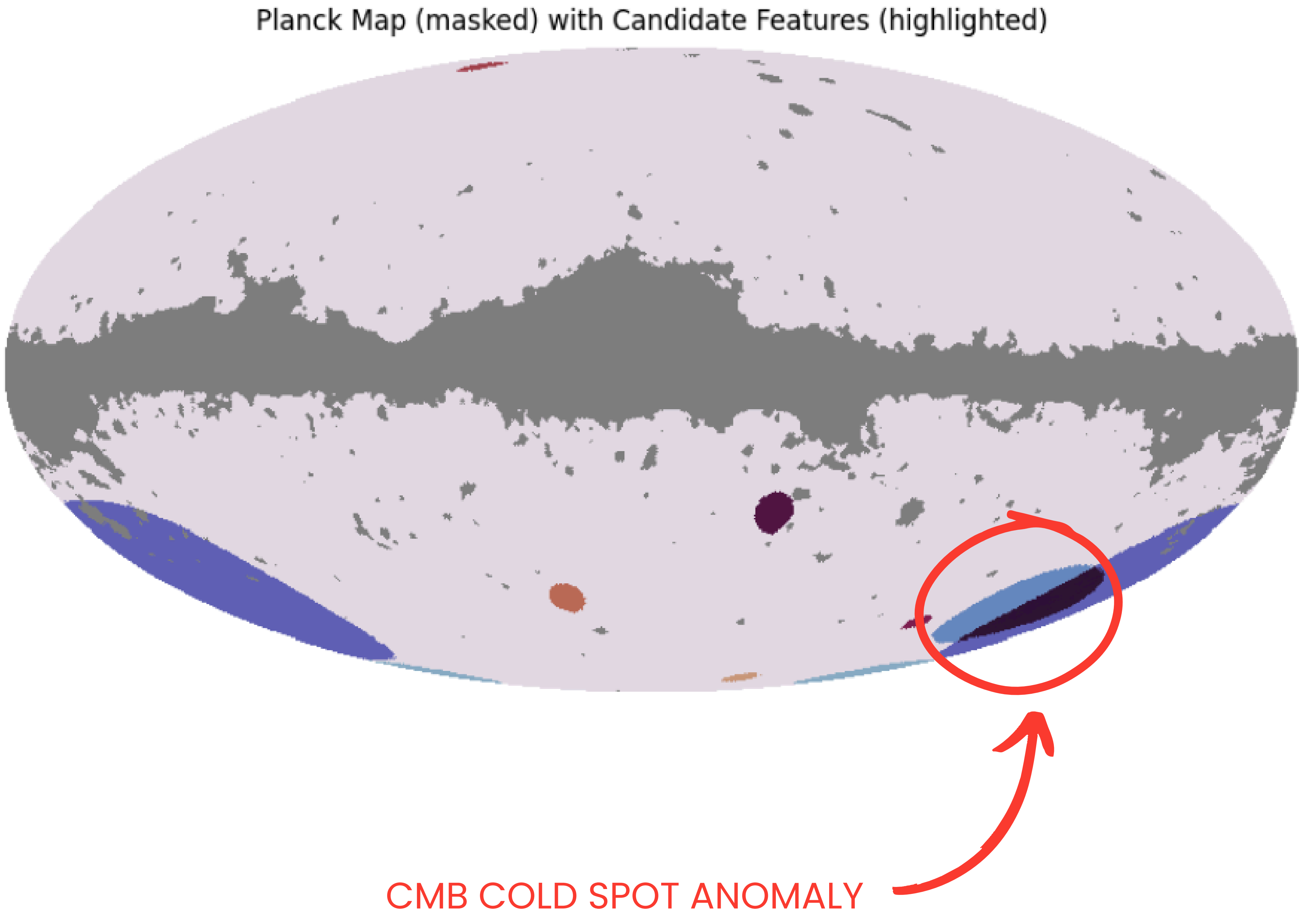
Edge Detection algorithm

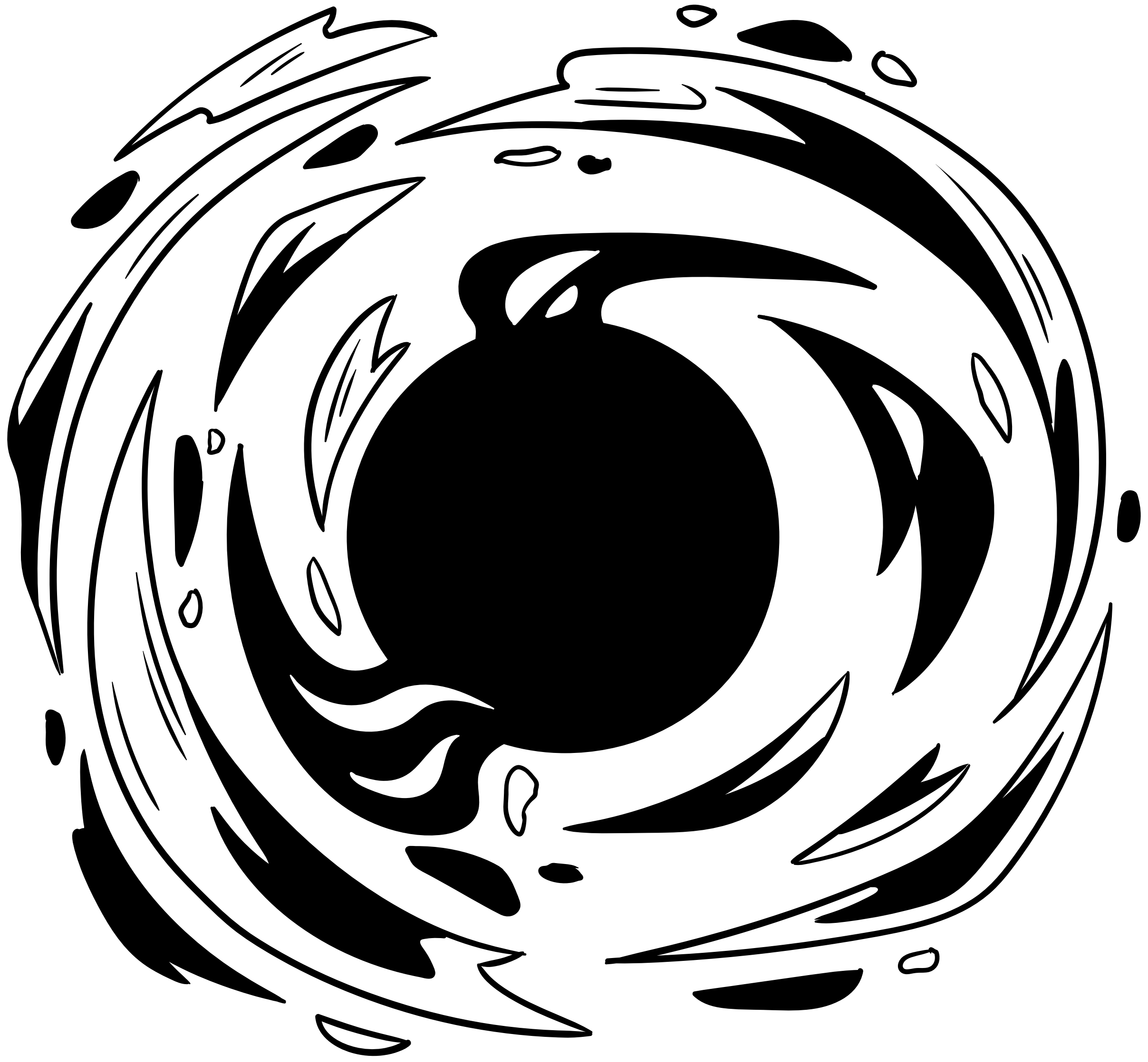
Blob parameter inference

Bayesian Analysis for evidences

CMB Cold Spot Anomaly focus

Higher resolution computation





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RESEARCH APPLICATIONS

Philosophical

The quest for answering the question: *'are we alone?'*

Cosmological

Establishes the need for improvements in theory regarding the origins and evolution of our universe
Opens up new pathways to explore theoretical physics

Wider scientific community

Applications developed for data analysis can be applied to wider community (e.g. medical, aeronautical, etc.)