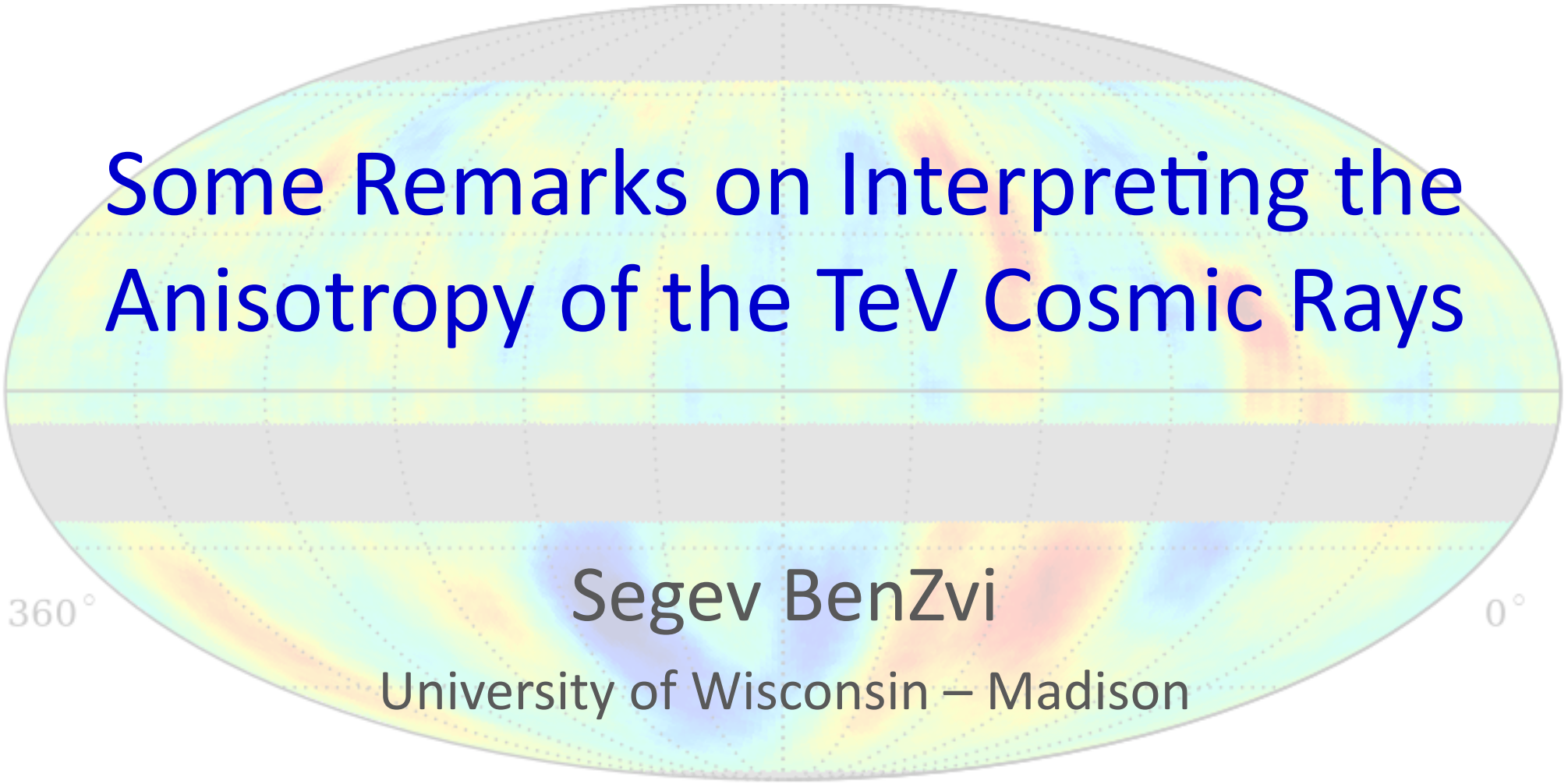

Some Remarks on Interpreting the Anisotropy of the TeV Cosmic Rays

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Issues You Should Know About

- Observing 10^{-4} effects in an air-shower array is a tricky business
- Ideally: estimate detector exposure from Monte Carlo simulation + known livetime
- In real life: drifts in detector response and atmospheric effects on air showers are quite hard to model to sufficient accuracy
- Solution: use actual data to estimate exposure (direct integration, time scrambling, etc.). These methods work, but cause some distortion in results

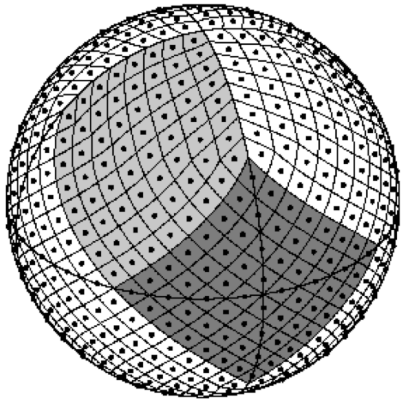
Note on Terminology

- Background estimation method:

$$\langle N(\alpha,\delta)\rangle = \sum_i \sum_j E_i(ha,\delta)\cdot\varepsilon(ha,\delta,t)\cdot R(t)\cdot\Delta\Omega_j\cdot\Delta t_i$$

Local arrival direction distribution

Event rate

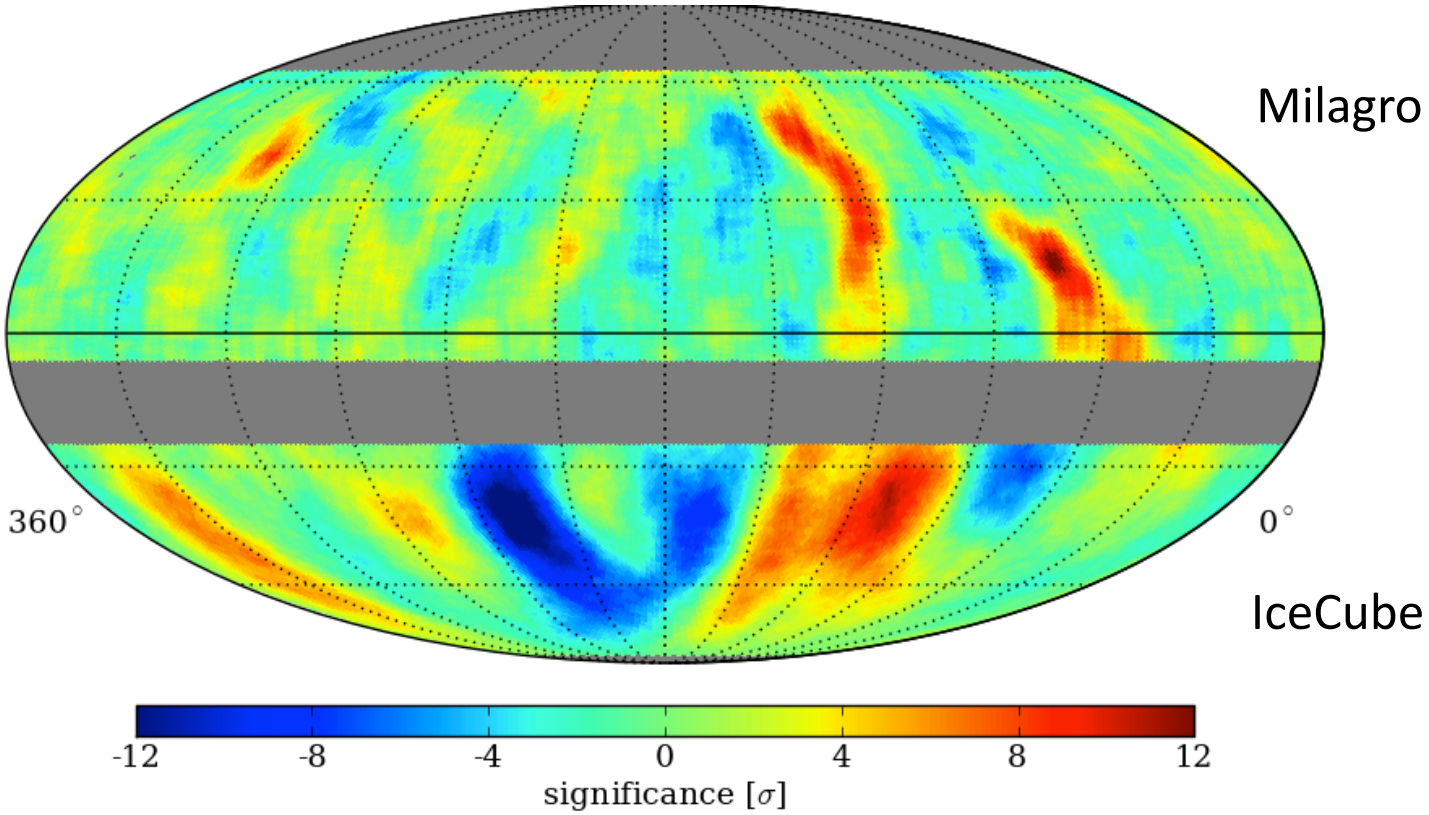


- Preserves distribution of local arrival directions

- Free parameter: integration time Δt
  - Typical values: 2h, 4h, …, 24h
  - Features larger than $\Delta t \times 15°$/hr are filtered out

Significance Map

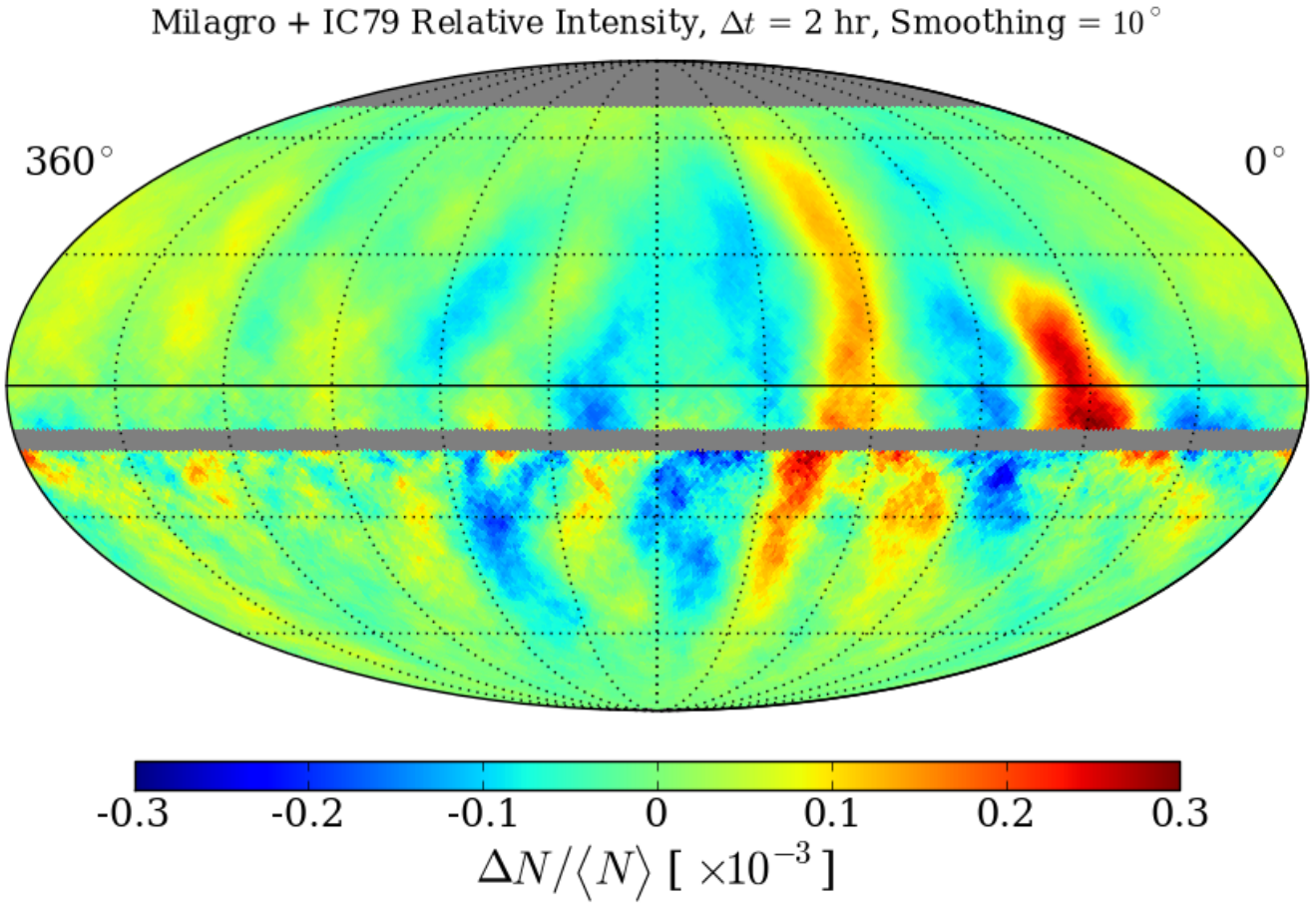
- IC22+IC40+IC59 (south) and Milagro data (north)



- 2h integration in exposure calculation, 10° smoothing
- Mixture of excesses and deficits (deeper in south)

Relative Intensity

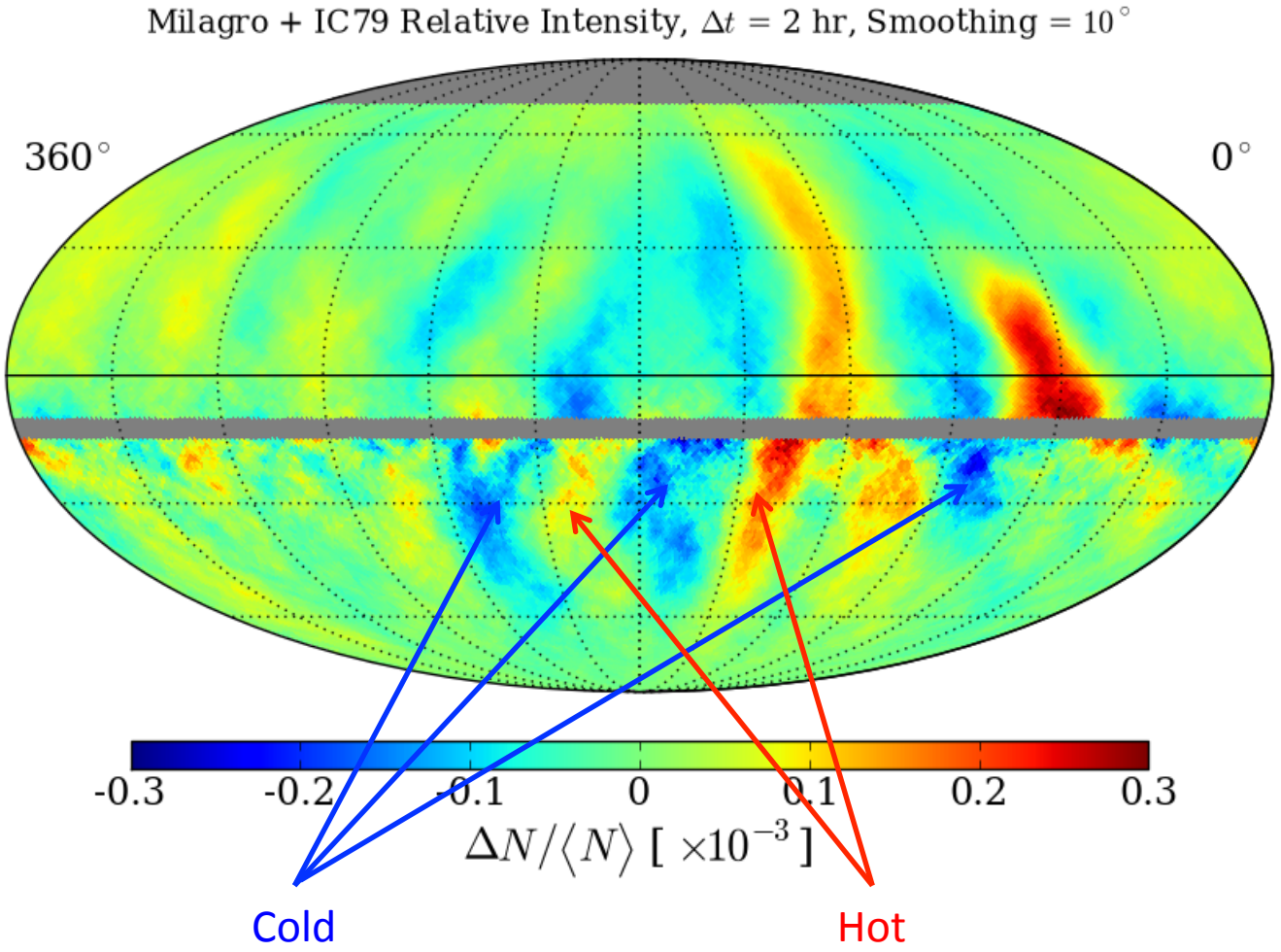
- Compare significance to relative intensity:



- Note differences at the edges of the maps

Issue: Map Artifacts

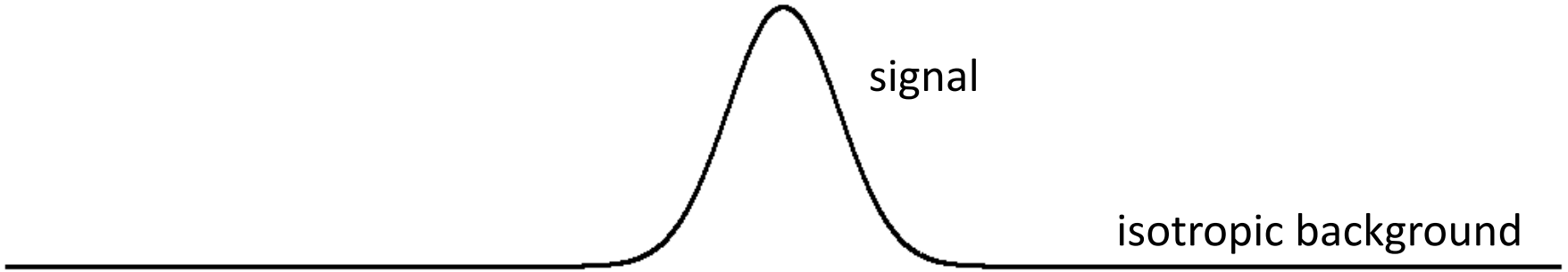
- Note the vertical striping that appears in both datasets:



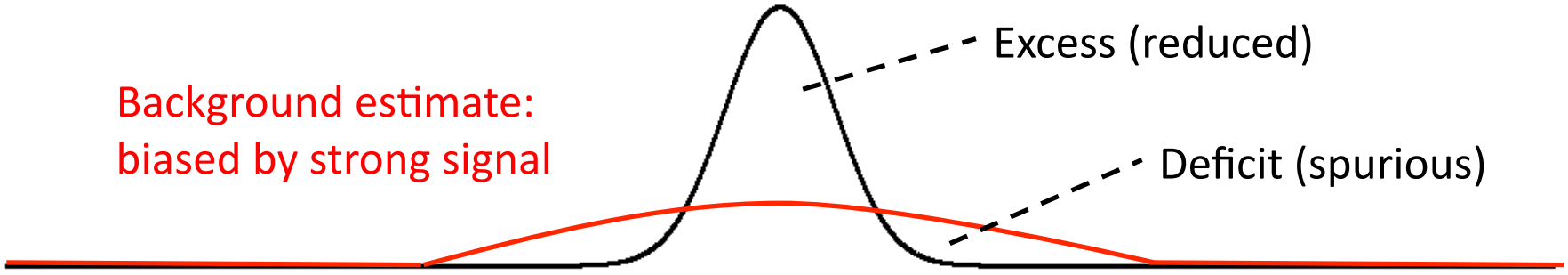
- Some of these are probably artifacts. Which ones?

Origin of Artifacts: Signal vs. Background

- Data contain signal plus huge background flux



- Use data themselves to estimate background:



Test Artifacts with Data Challenges

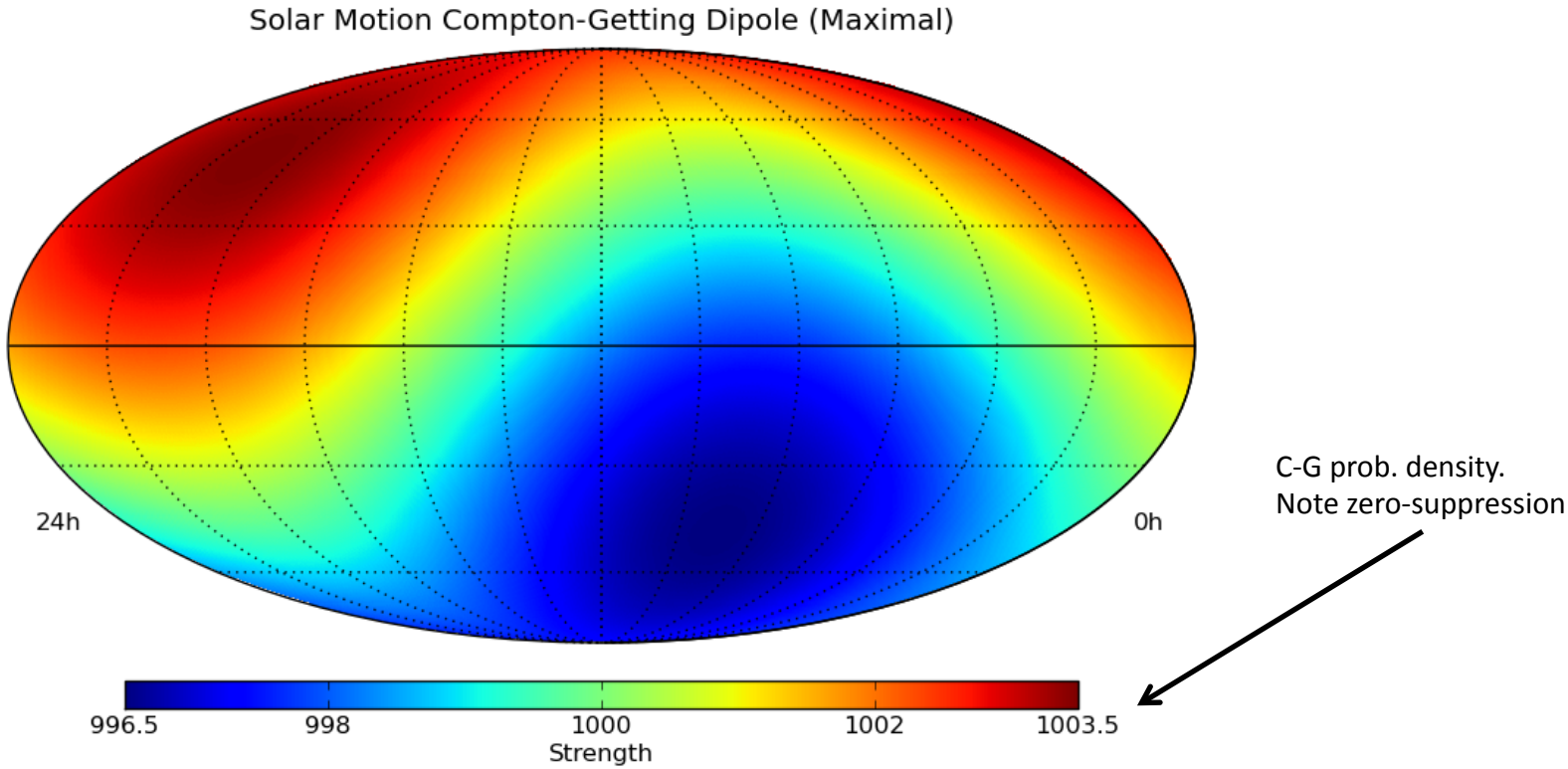
- Concept: inject a small fake signal into a much larger exposure-weighted background and see if the analysis can recover the signal

- Create random maps by re-sampling data
  - Sample from IceCube local acceptance: get (ϑ, φ)
  - Assign a real event time t to phony (ϑ, φ) to get (α, δ)
  - Repeat until fake data set is complete

- Yields an isotropic background that preserves the local coordinate distribution and the event rate of the real detector

Challenge #1: Compton-Getting Effect

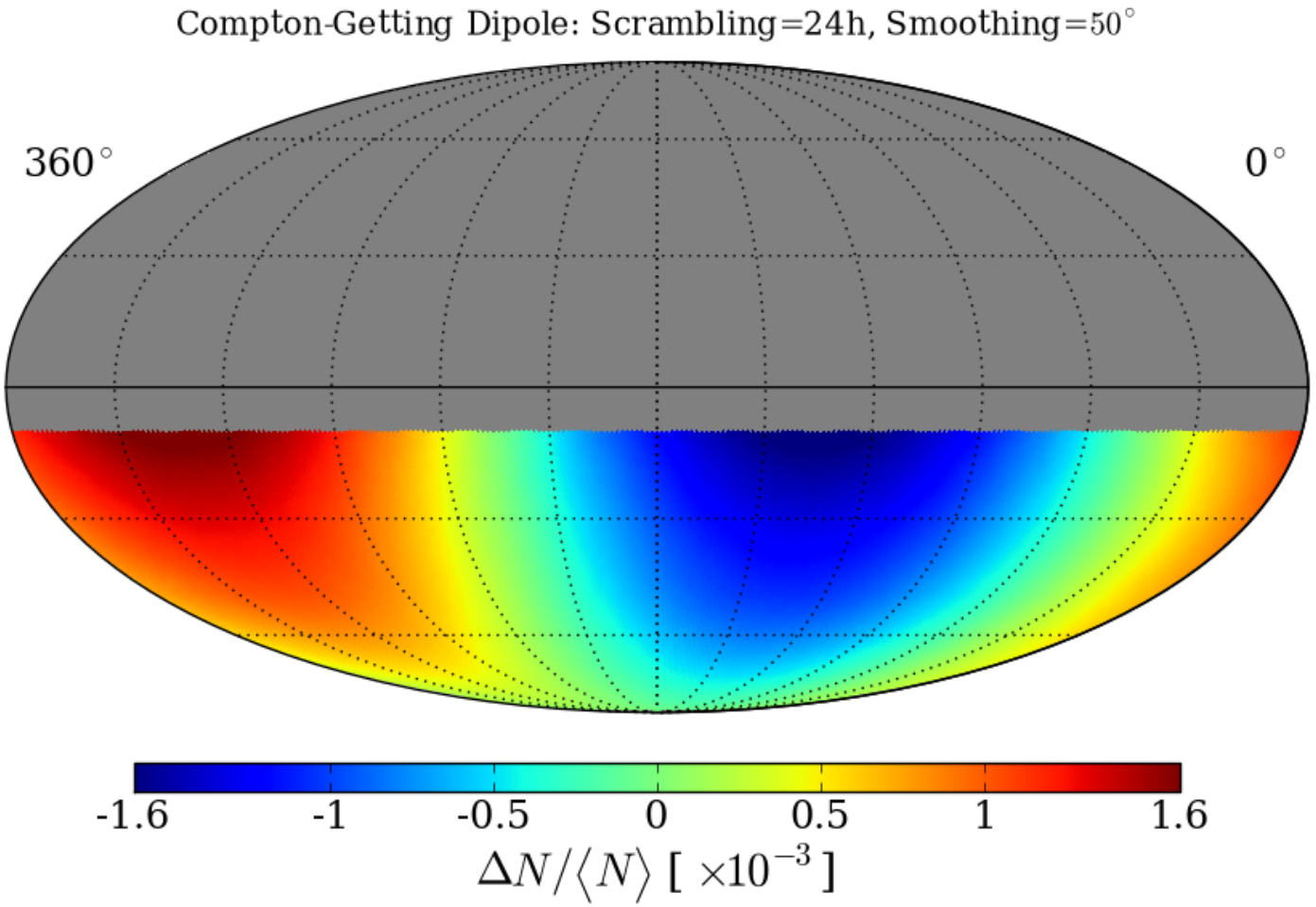
- If a physical Compton-Getting dipole existed, what would it look like in the data?



- Method: resample IceCube events to randomize the sky, then inject the *known* dipole and analyze.

Compton-Getting "Results"

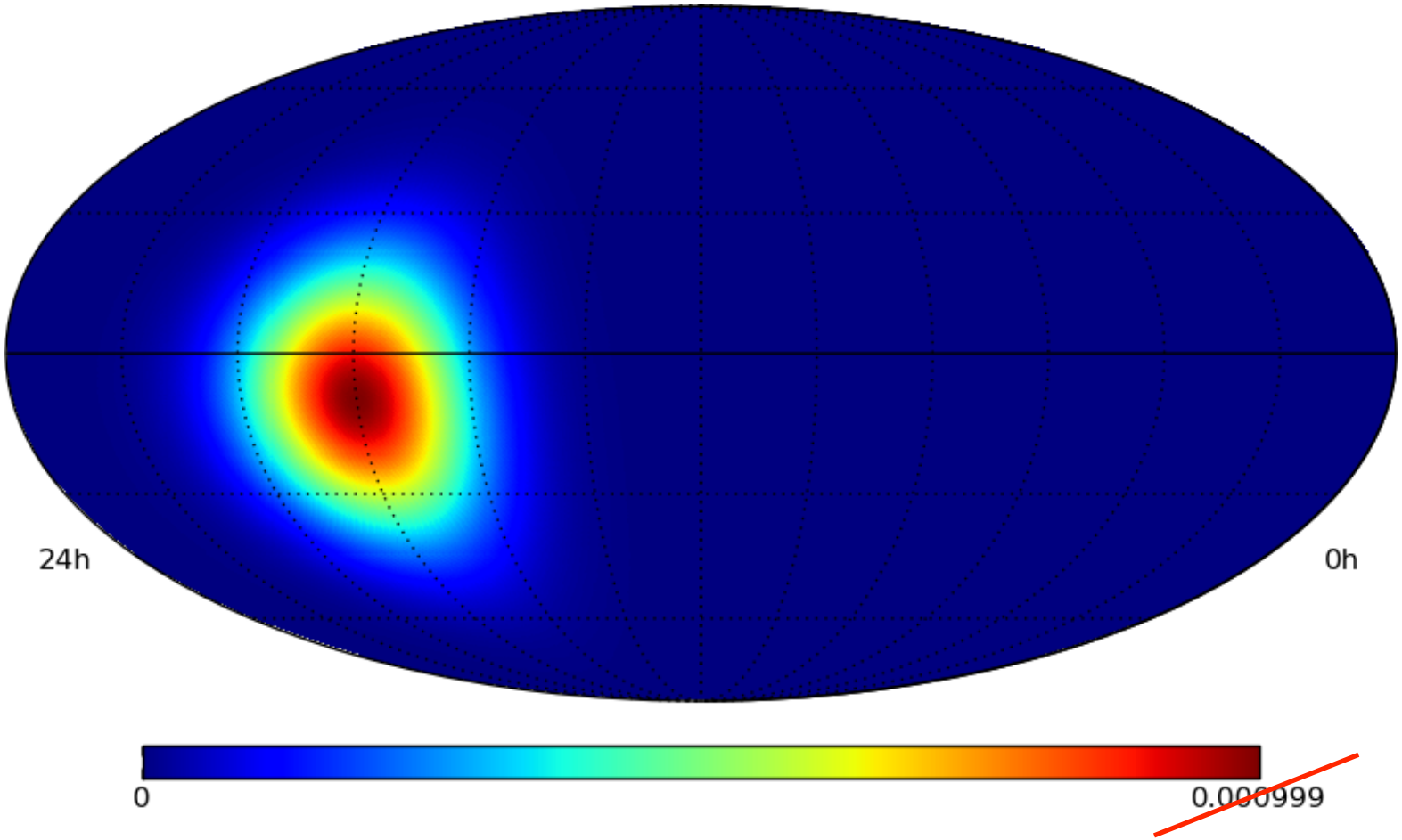
- A distorted dipole is recovered:



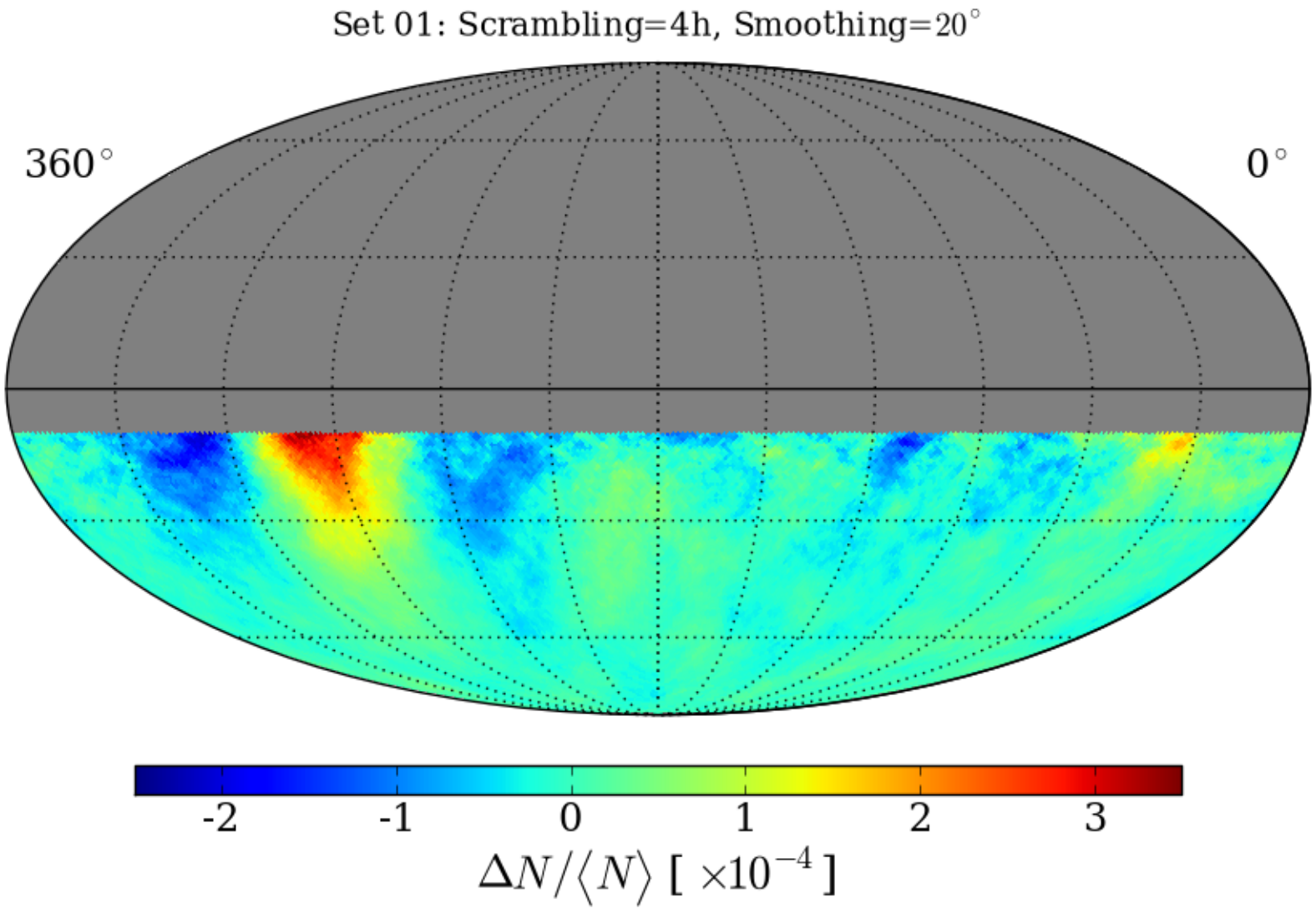
- Recovered phase OK; amplitude decreases by 1/2

Challenge #2: Source + Flat Bkgrd

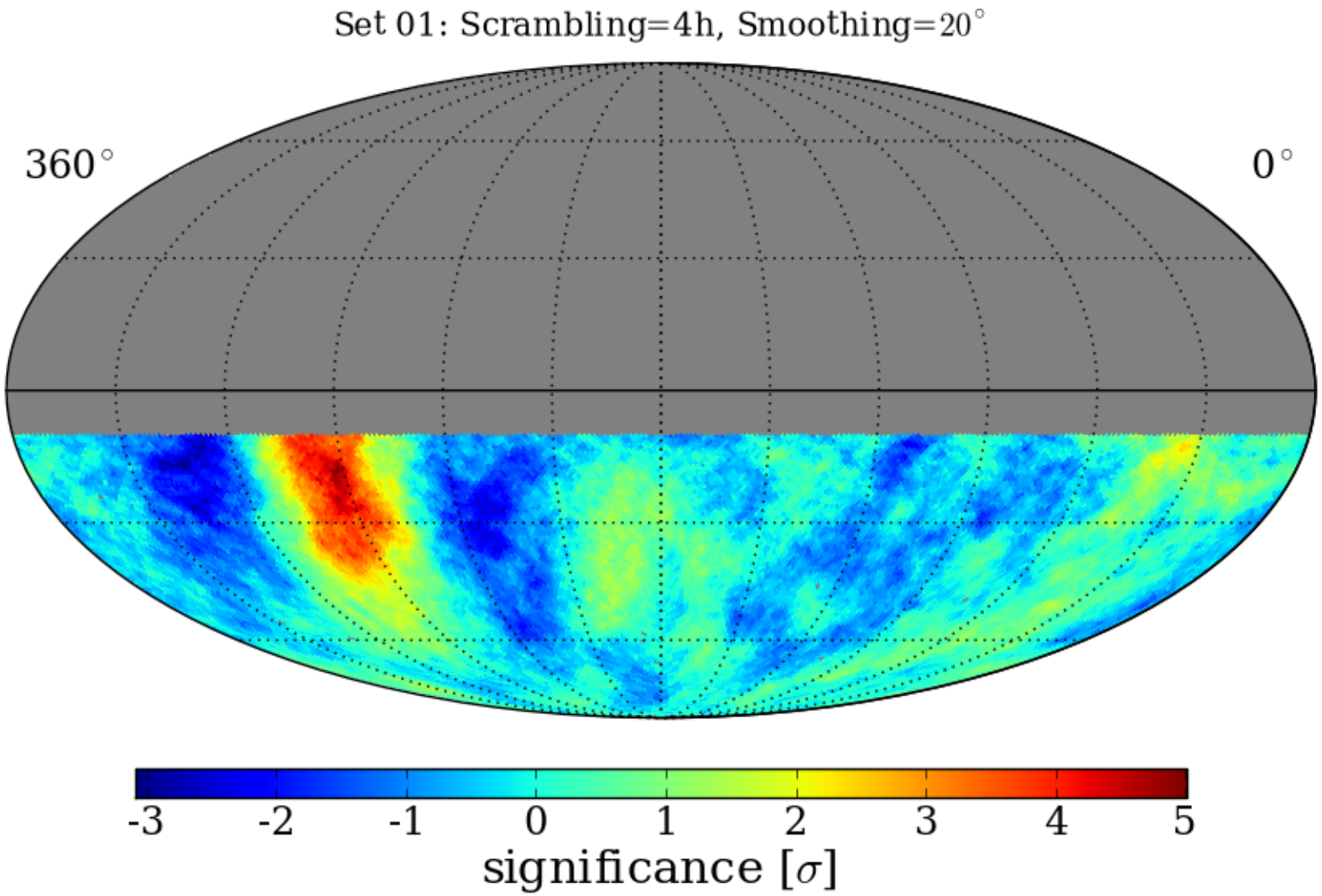
- Source PDF: (α=270°, δ=10°), width = 20°
- Amplitude = 10^{-3}



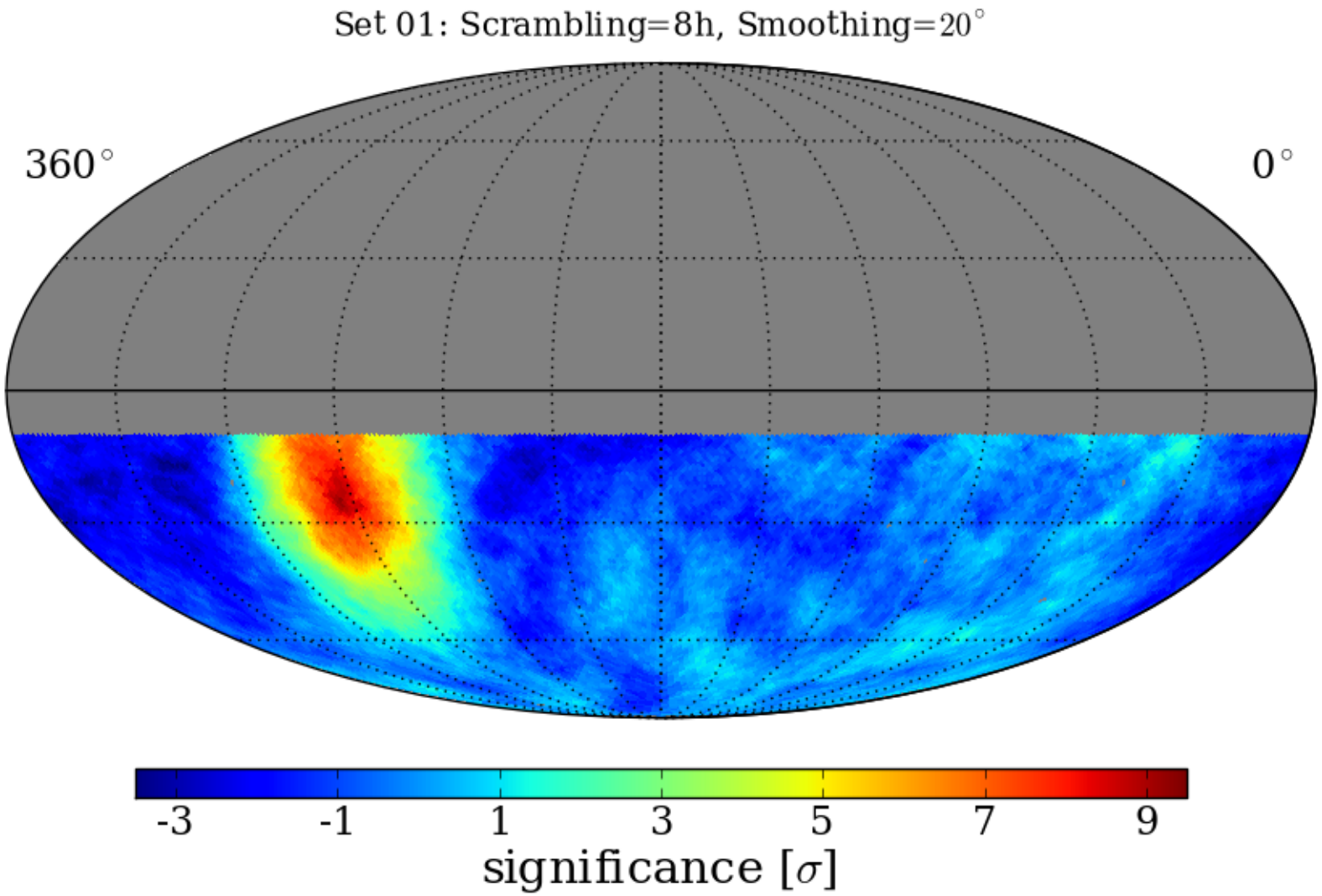
Source + Flat Background "Results"



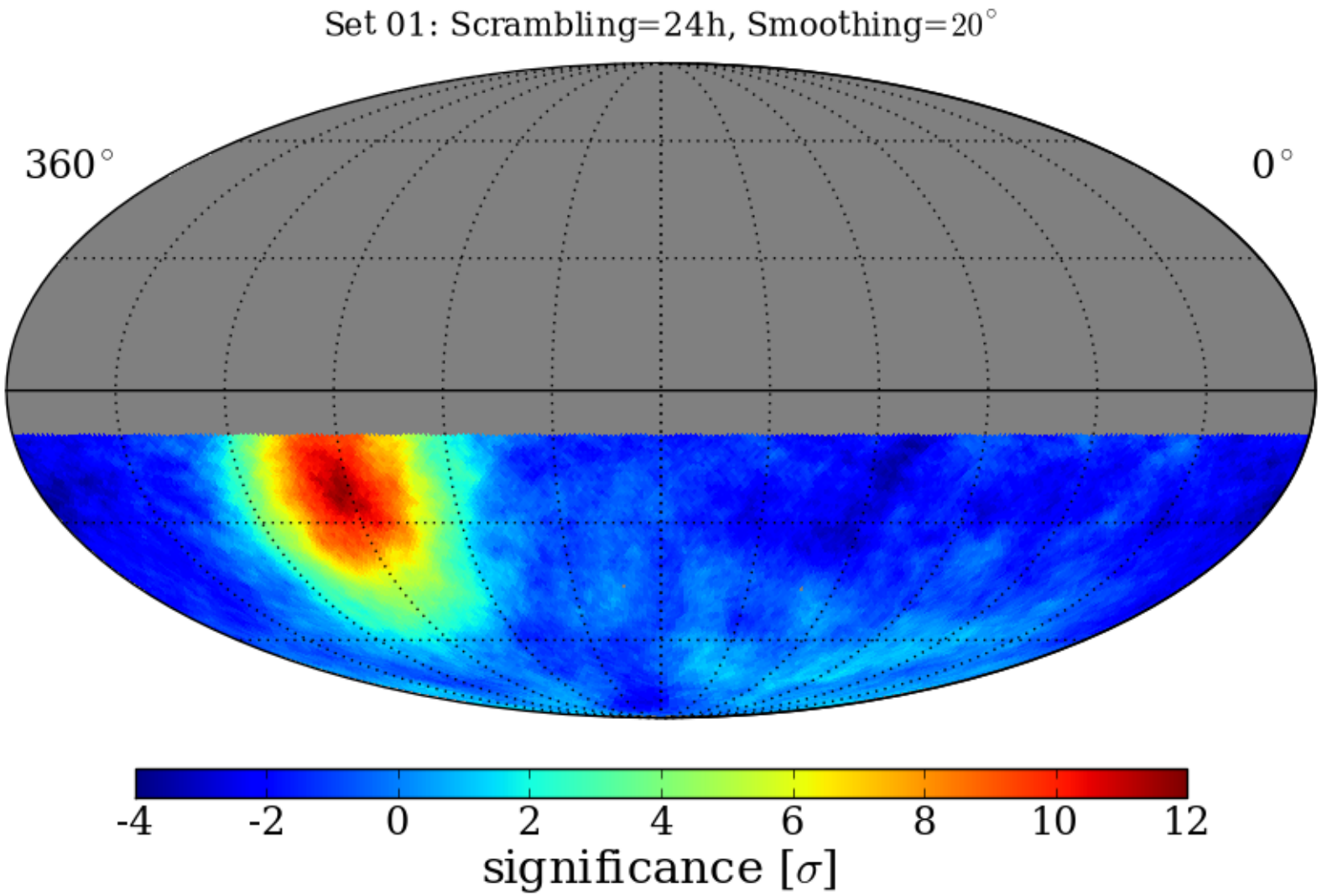
Significance: 4h Integration Period



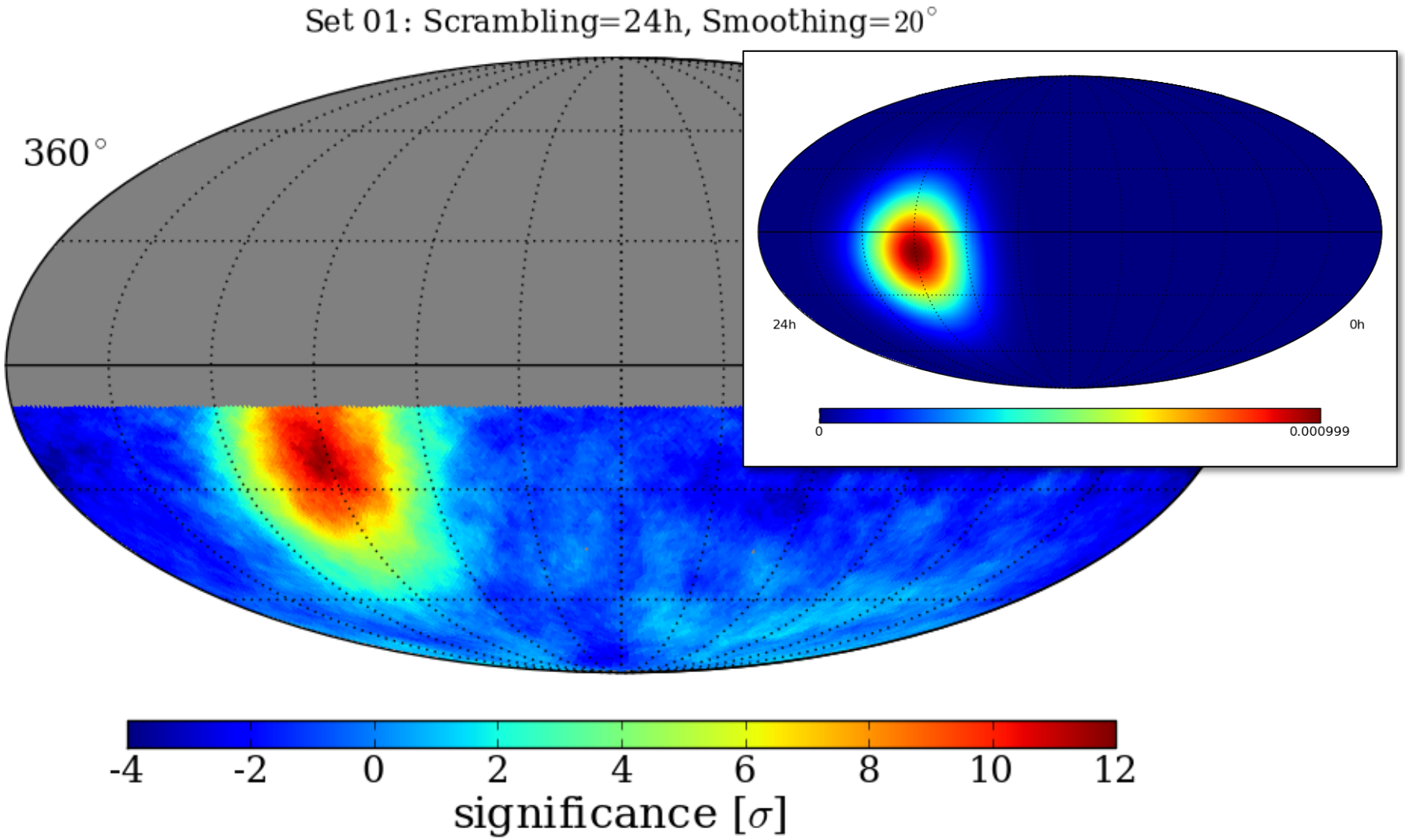
Effect of Integration Period: 8h



Effect of Integration Period: 24h

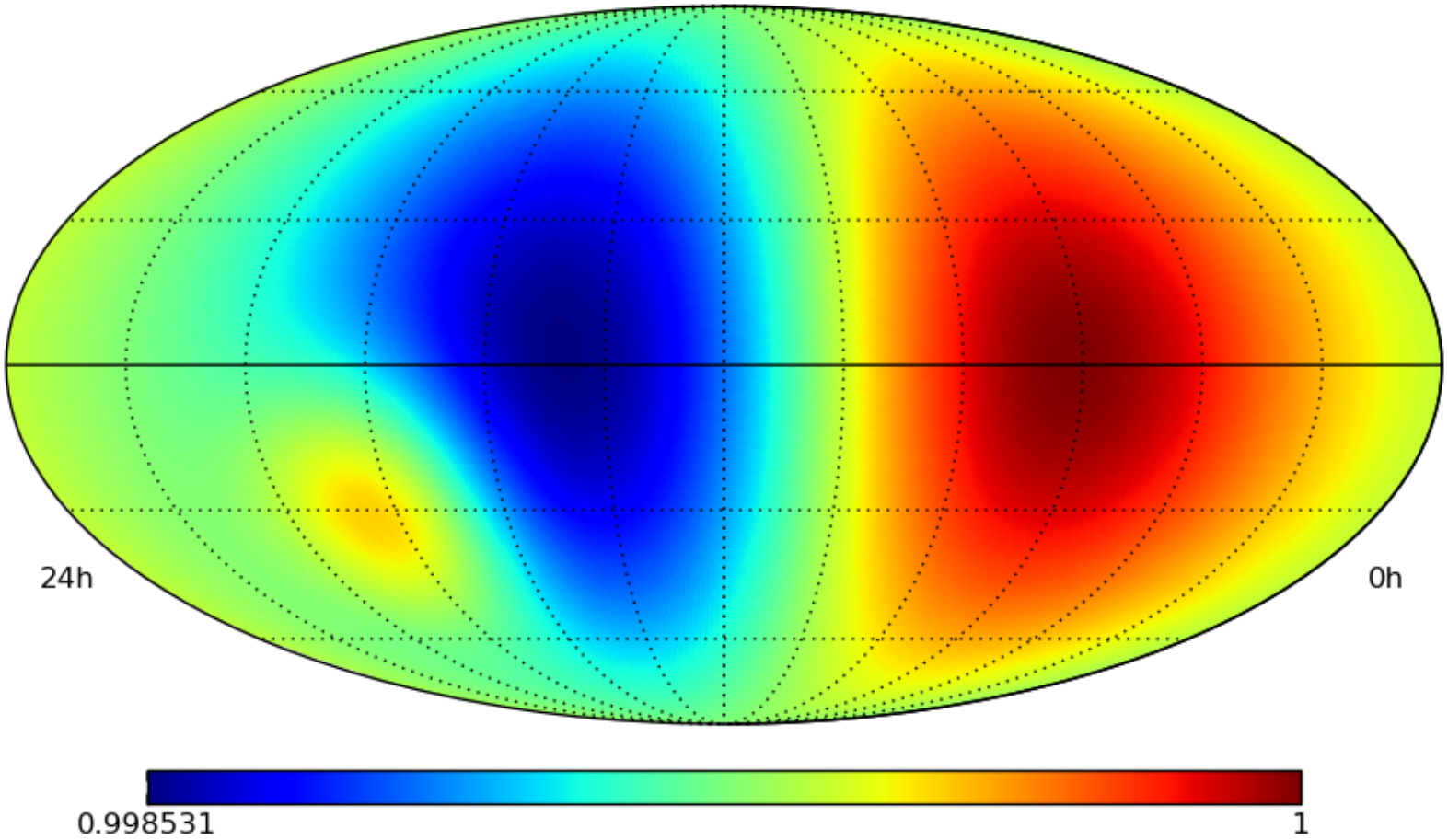


Effect of Integration Period: 24h



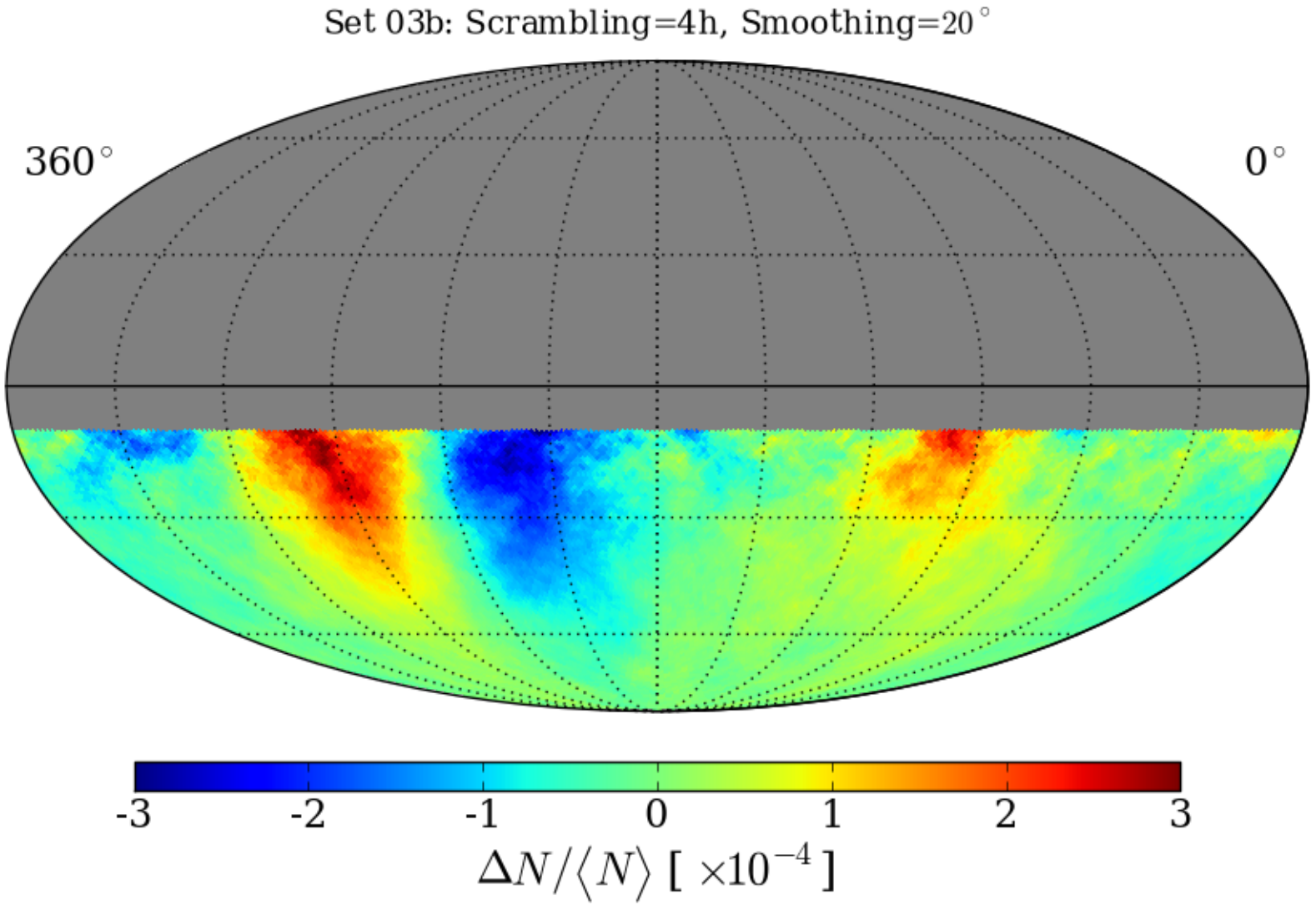
Challenge #3: Source + Bkg + DQ

- Isotropic background, amplitude = 1
- Dipole: (α=90°, δ=0°), amplitude = 6.4×10^{-4}
- Quadrupole: (α=65.6°, δ=0°), amplitude = 2.1×10^{-4}
- "Source": (α=270°, δ=-30°), amplitude = 6.4×10^{-4}, width = 20°

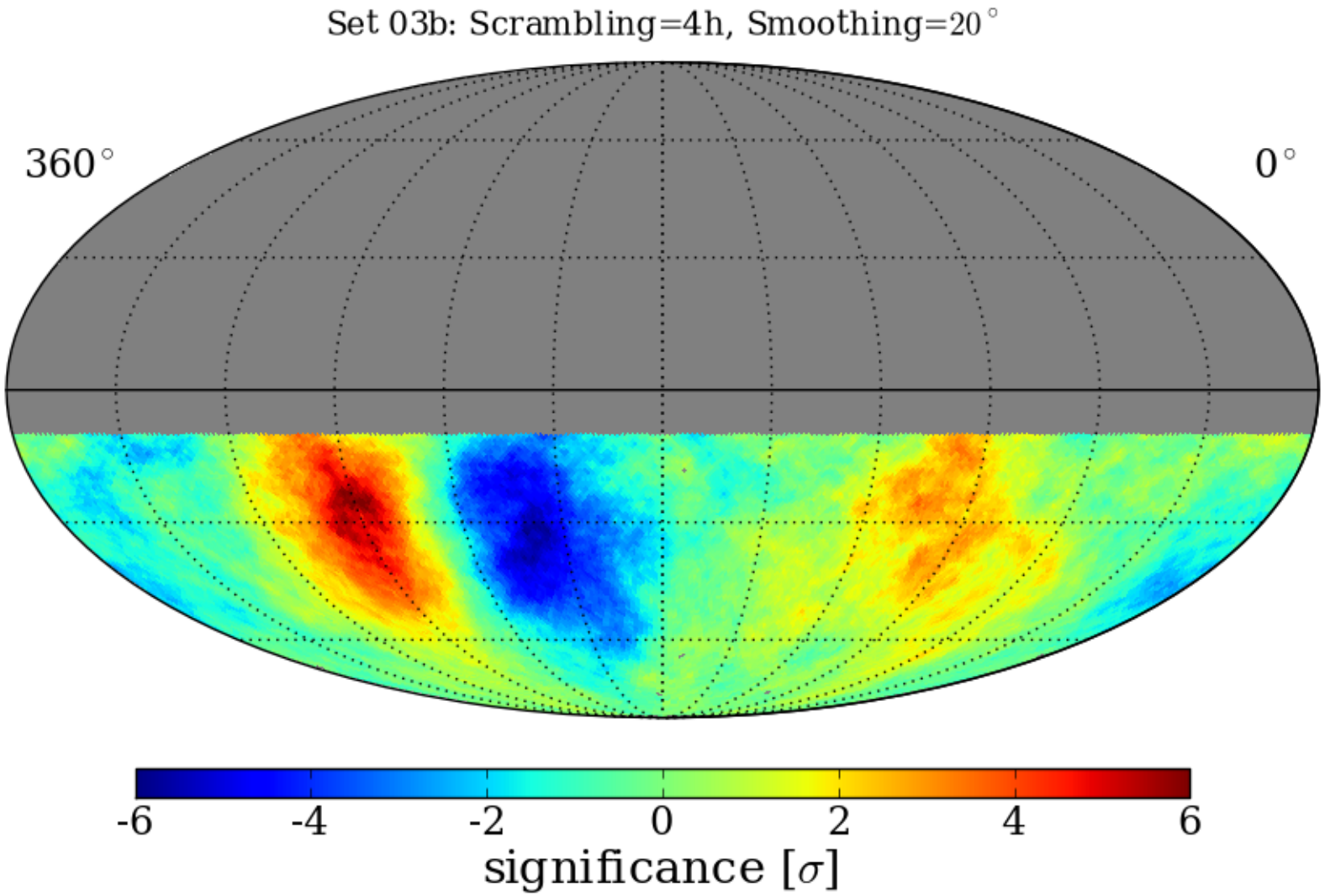


Challenge #3 Results

- Excess with equally deep neighboring deficit

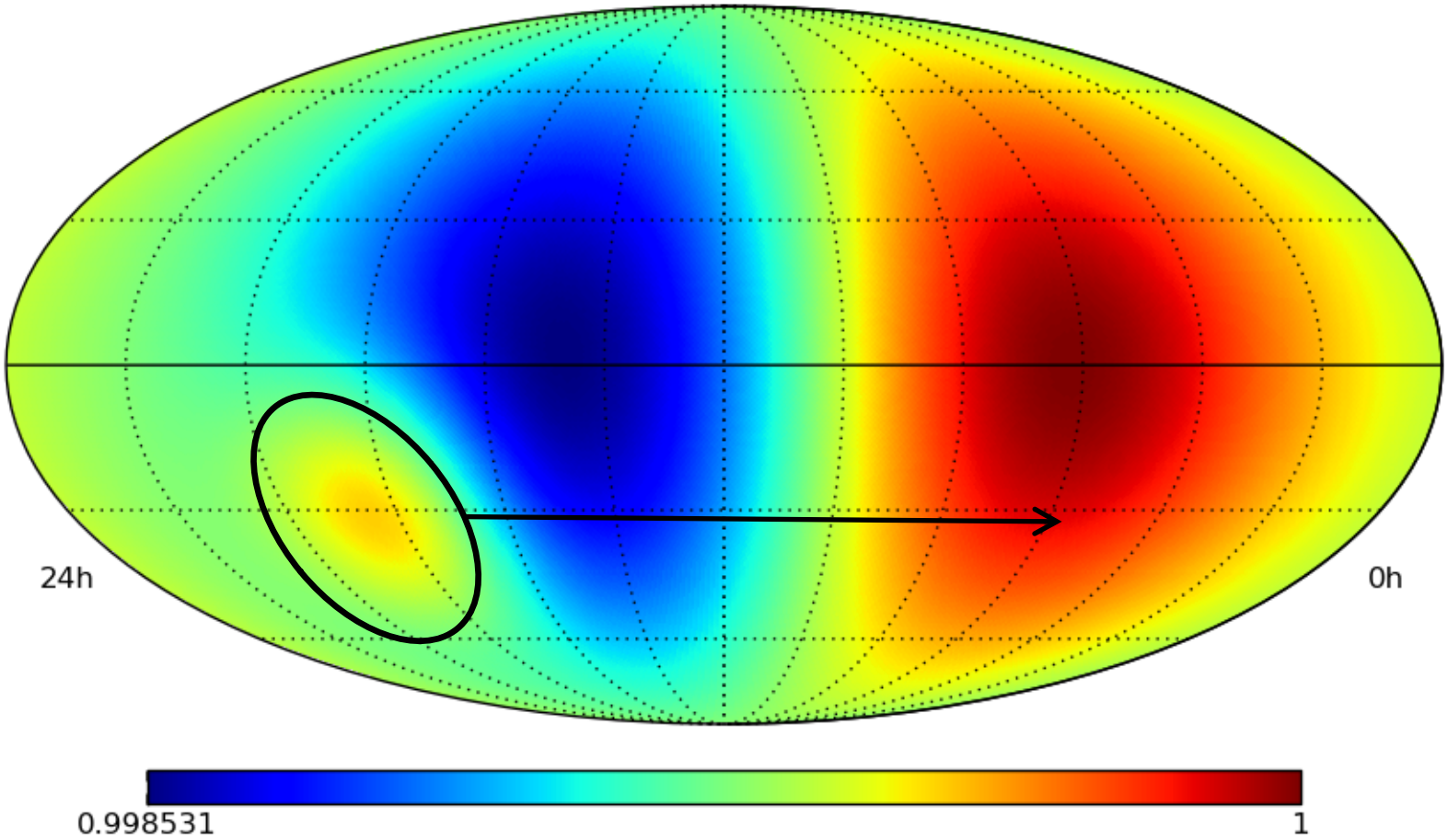


Challenge #3 Results



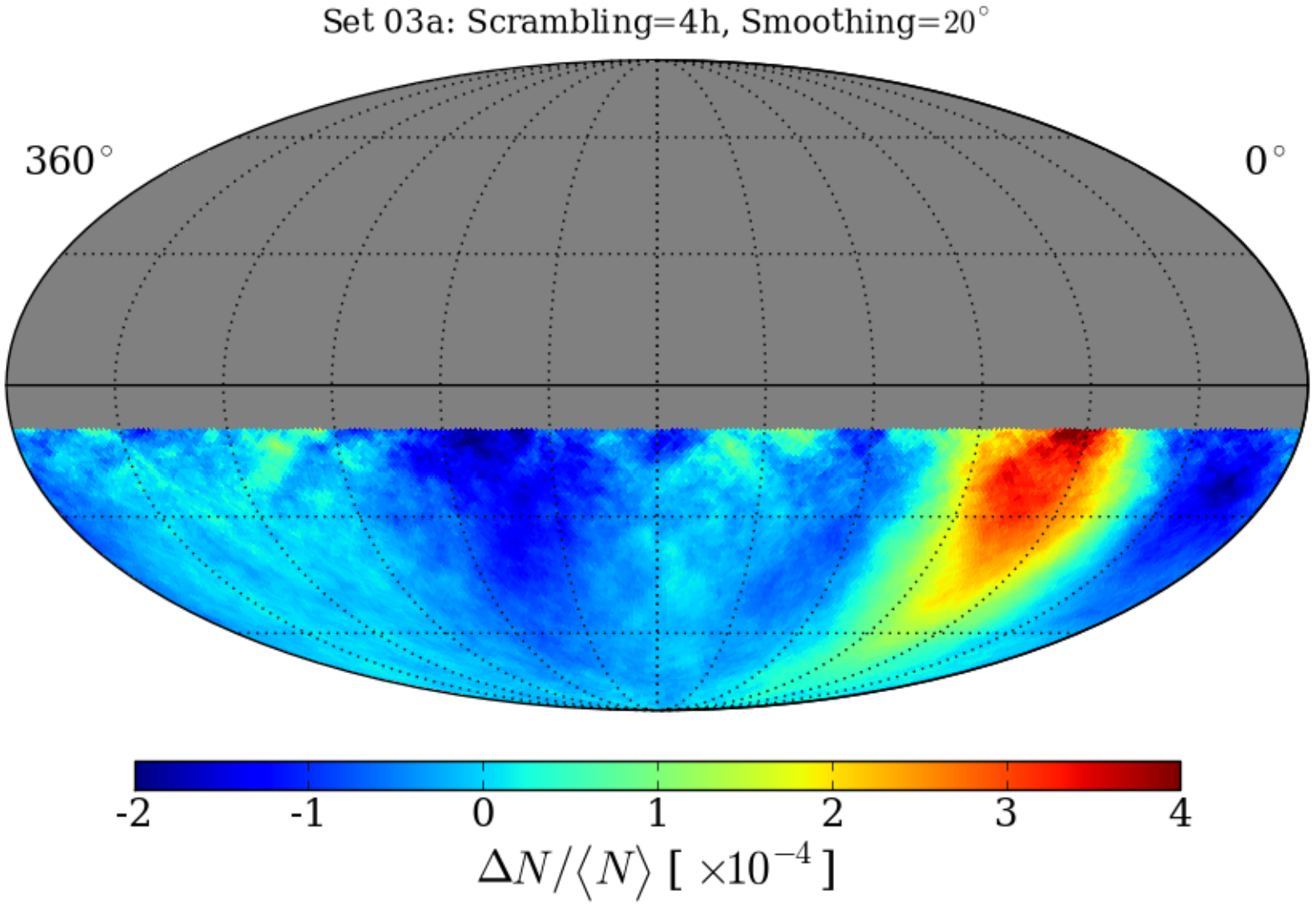
Challenge #4: Source + Bkg + DQ

- Isotropic background, amplitude = 1
- Dipole: (α=90°, δ=0°), amplitude = 6.4×10^{-4}
- Quadrupole: (α=65.6°, δ=0°), amplitude = 2.1×10^{-4}
- "Source": (α=90°, δ=-30°), amplitude = 6.4×10^{-4}, width = 20°

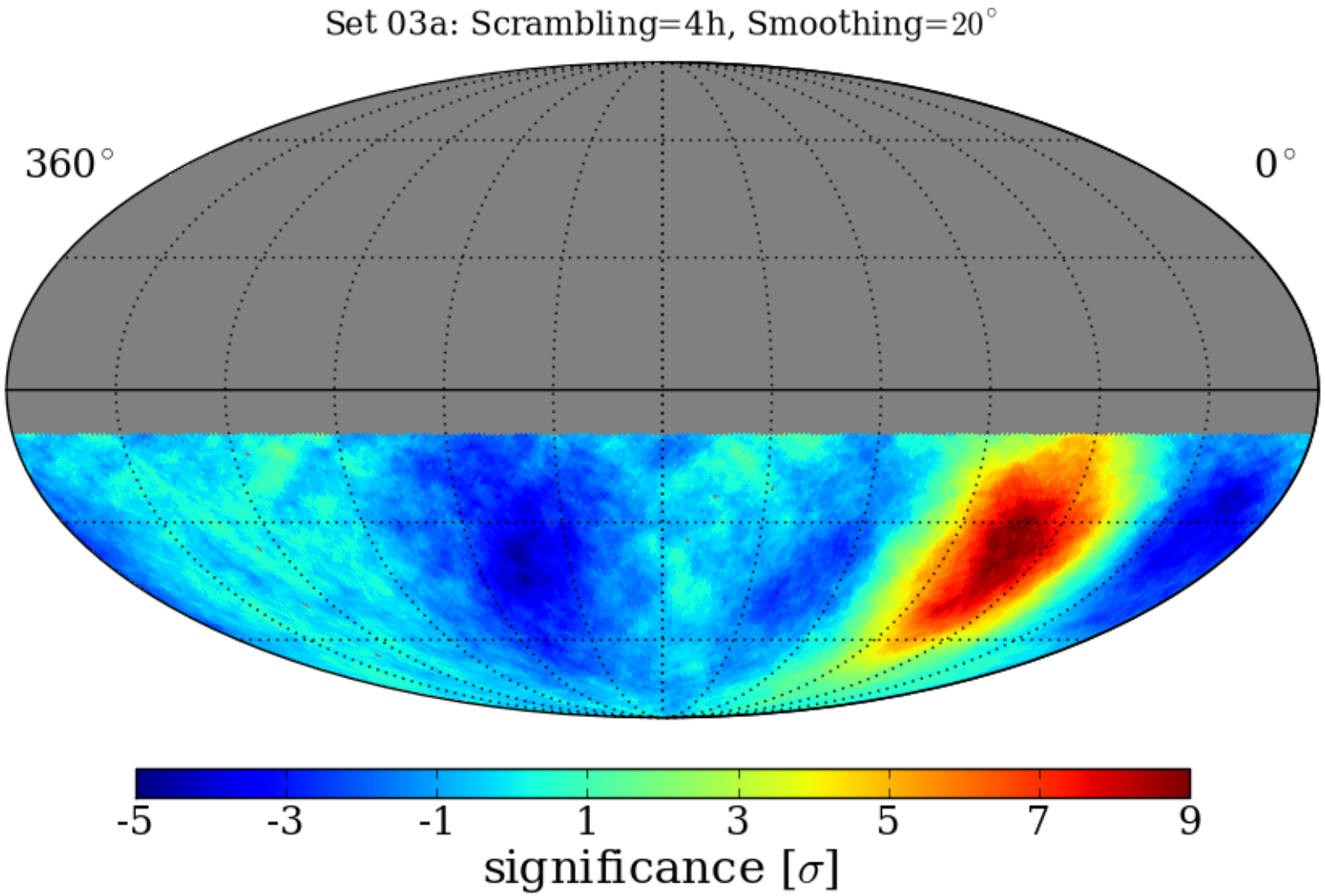


Challenge #4 Results

- Strong excess, smaller neighboring deficits



Challenge #4 Results



Comments

- Partial-sky coverage will bias observations of structure on largest scales (obvious)
- Exposure calculation creates artifacts in the significance and relative intensity maps
- Shape and size of artifacts depend on:
  - Length of integration period in exposure calculation
  - Relative positions and strengths of features on different angular scales
- Is there a better way to calculate detector exposure?