Revisiting the CMB anomalies at large scale
The impact of the Local universe

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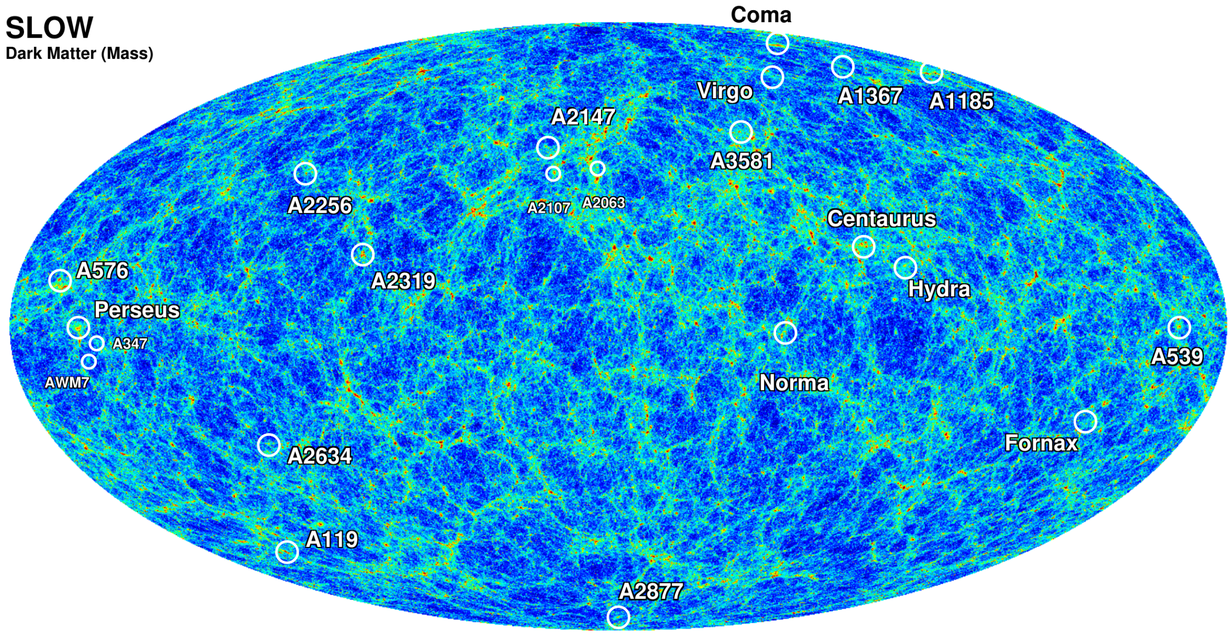
SLOW - Simulating the LOcal Web

Dolag, Sorce, Pilipenko, Hernández-Martínez, Valentini, Gottlöber, Aghanim & Khabibullin *2302.10960*

Constrained hydrodynamical simulation of the local universe

- Initial conditions reconstructed from the observed galaxy peculiar velocity field *Sorce 1806.09633*
- Evolution computed using OPENGADGET3, including full galaxy formation physics
- Cosmological parameters compatible with Planck
- 2×1536^3 gas and dark matter particles
- Box size: $500\ \mathrm{Mpc}/h$



From 2302.10960

Sunayev-Zeldovich effect

Inverse Compton scattering of CMB photons by high-energy electrons, mainly found in galaxy clusters

tSZ (thermal)

$$\frac{\Delta T^{\mathrm{tSZ}}}{T_{\mathrm{CMB}}}(\nu, \hat{\Omega}) \propto g(\nu) \int \mathrm{d}l \, n_e(\hat{\Omega}, l) T_e(\hat{\Omega}, l)$$

kSZ (kinetic)

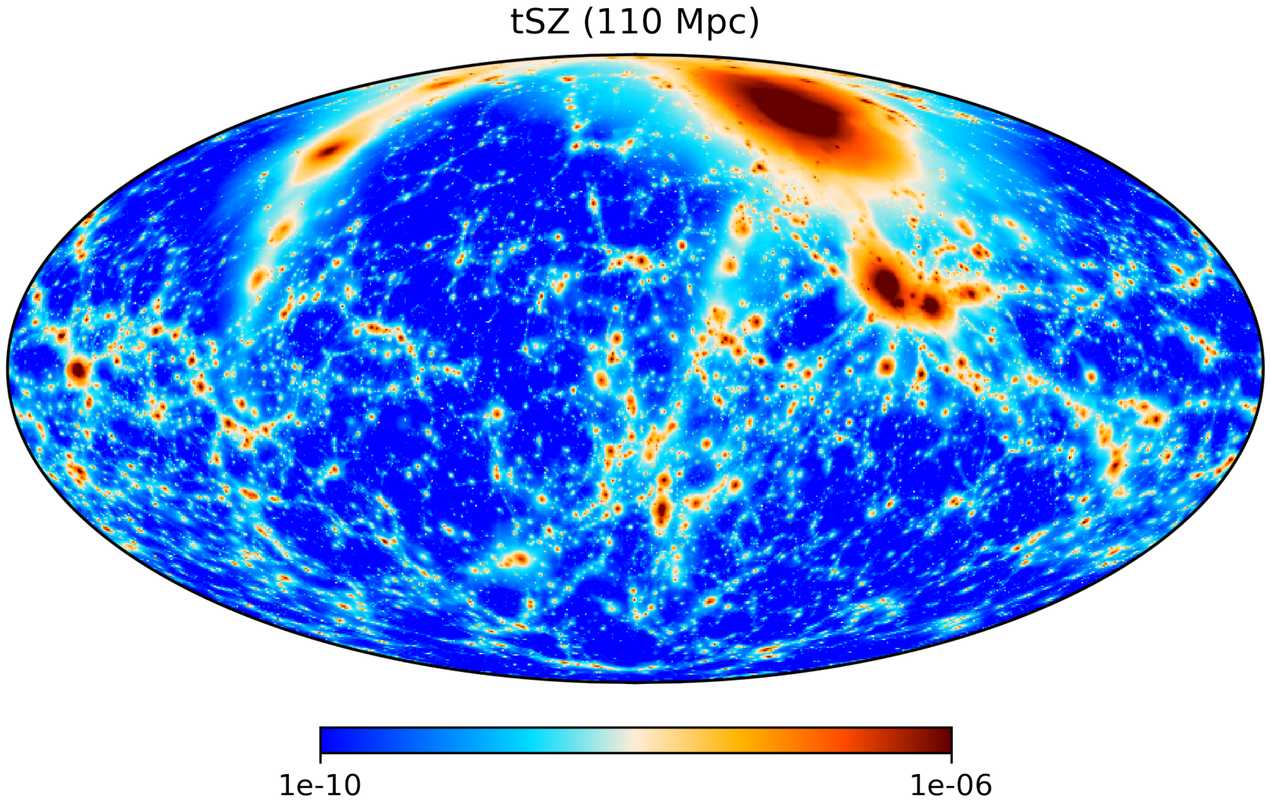
$$\frac{\Delta T^{\mathrm{kSZ}}}{T_{\mathrm{CMB}}}(\hat{\Omega}) \propto \int \mathrm{d}l \, \hat{\Omega} \cdot v_e(\hat{\Omega}, l) \, .$$

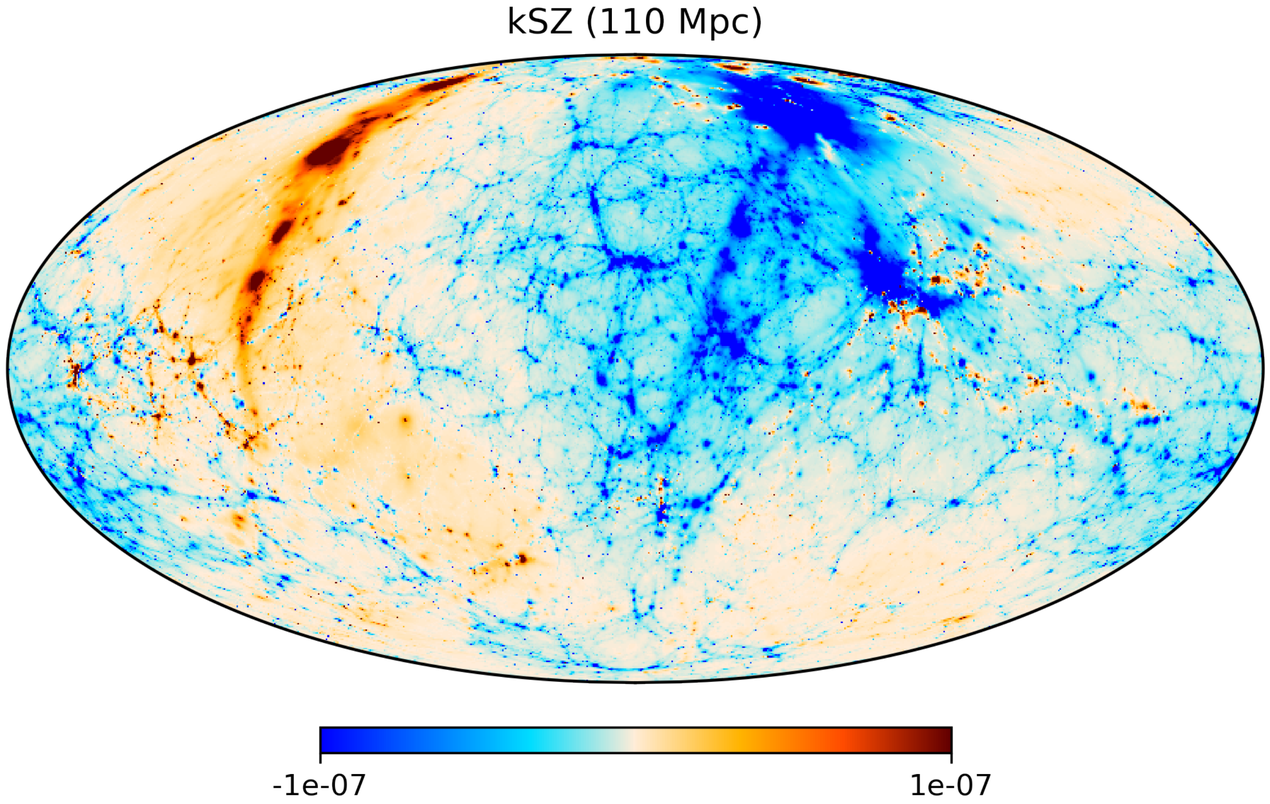
n_e, T_e, v_e: electron number density, temperature and bulk velocity

Integrals computed in the simulations using SMAC *(Dolag et al, astro-ph/0505258)*

tSZ and kSZ maps

From the (very) local universe





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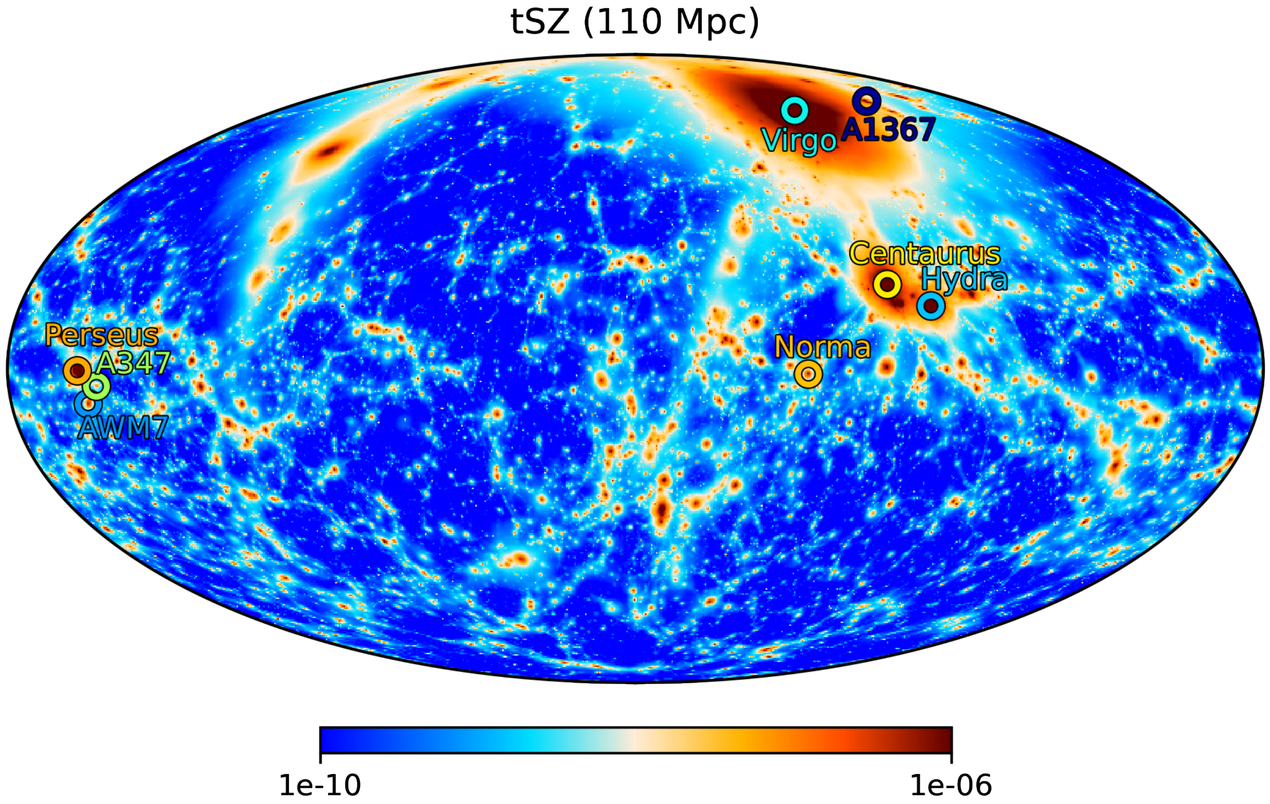

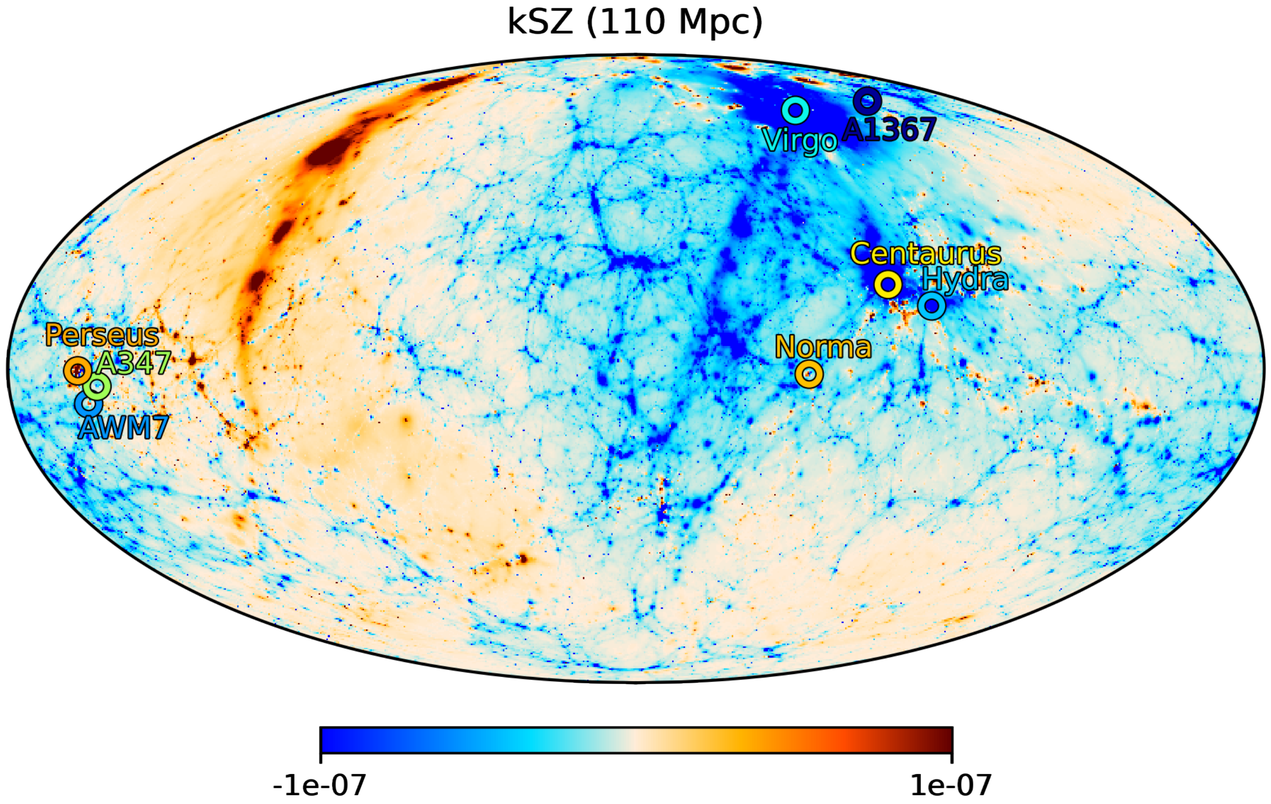

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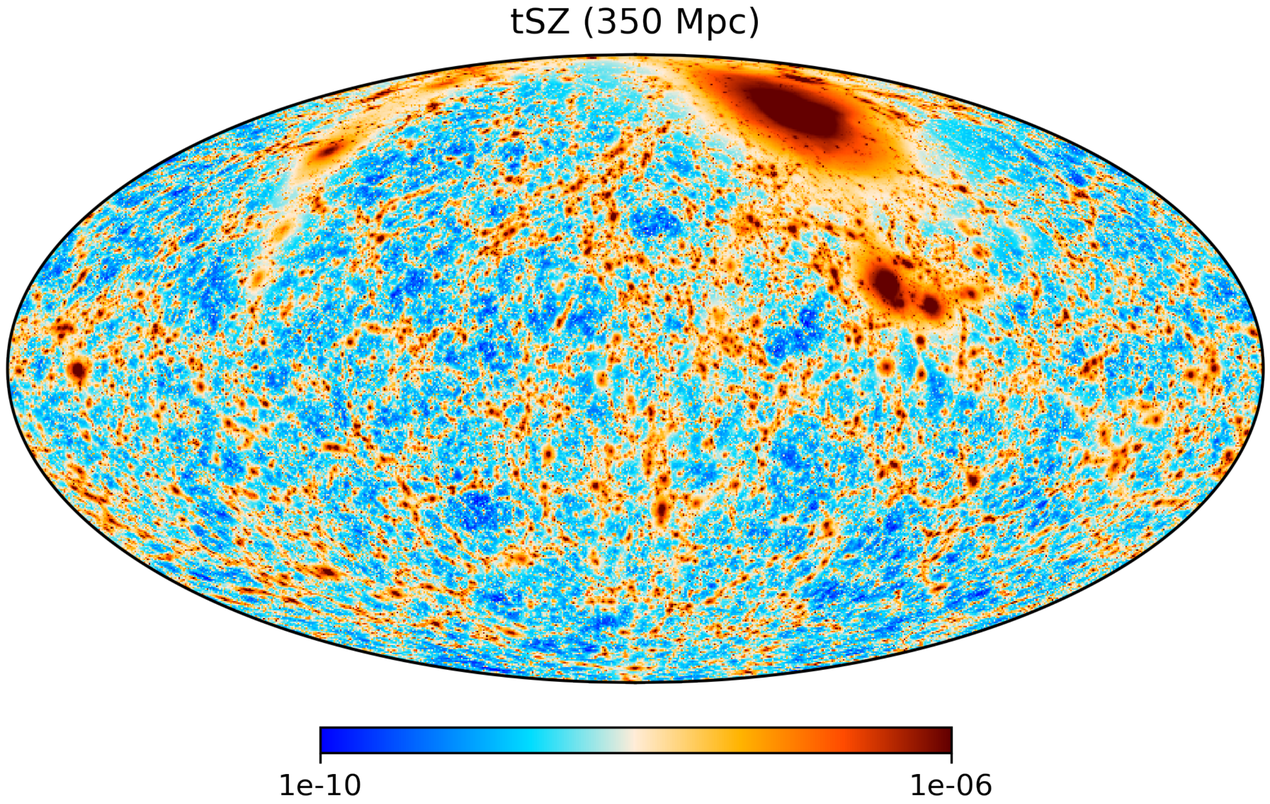
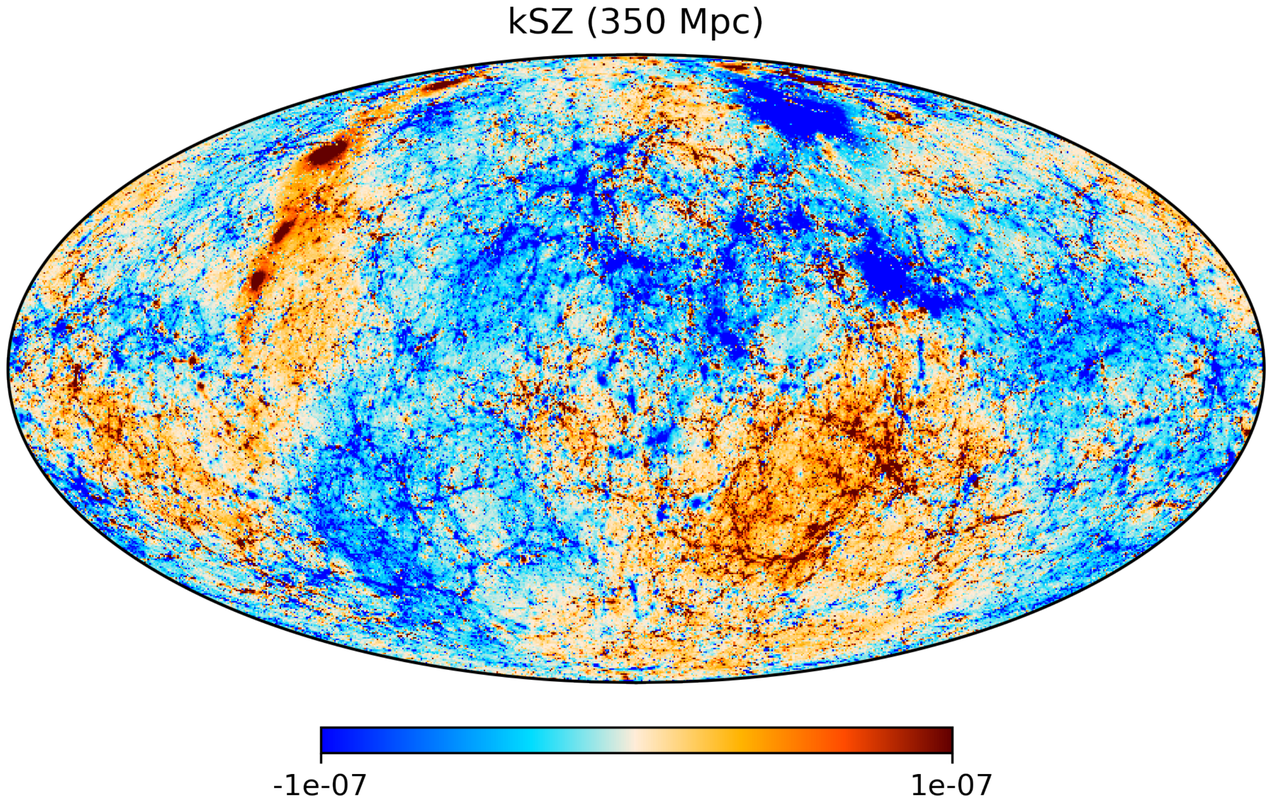
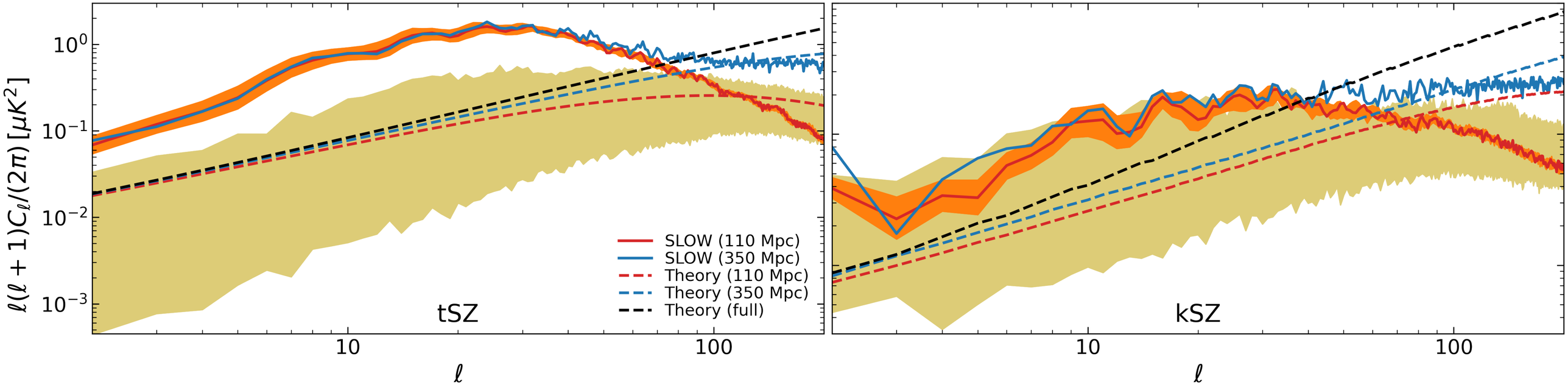




tSZ and kSZ power spectra

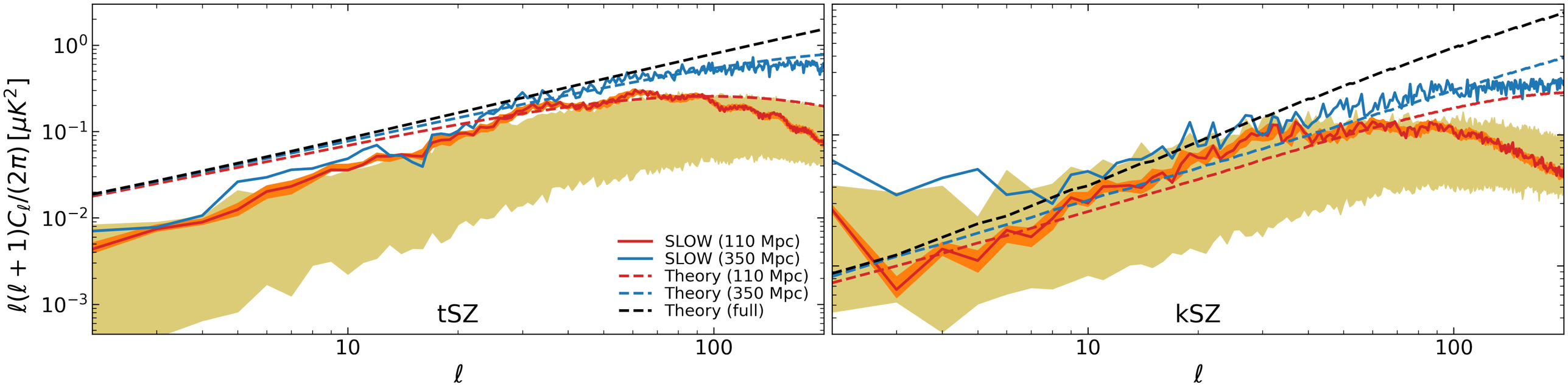
From the local universe



- Error bars (90% intervals) on C_ℓ obtained by shifting the origin (by 1 Mpc, or by more than 110 Mpc)
- Theoretical C_ℓ's: computed with CLASS-SZ *(https://github.com/CLASS-SZ/class_sz, Bolliet et al)* for different ranges of integration: up to $z = 5$ (full), $z \sim 0.08$ (350 Mpc) and $z \sim 0.025$ (110 Mpc).

tSZ and kSZ power spectra

From the local universe, masking Virgo



- Error bars (90% intervals) on C_ℓ (110 Mpc) obtained by shifting the origin (by 1 Mpc, or by more than 110 Mpc)
- Theoretical C_ℓ's: computed with CLASS-SZ *(https://github.com/CLASS-SZ/class_sz, Bolliet et al)* for different ranges of integration: up to $z = 5$ (full), $z \sim 0.08$ (350 Mpc) and $z \sim 0.025$ (110 Mpc).
- Most of the large scale signal comes from Virgo (and Centaurus)

CMB large-scale anomalies

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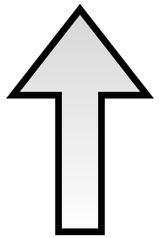

Does the local universe have any impact on these anomalies through its SZ signals?

CMB large-scale anomalies
In Planck PR4 data

Planck collaboration *2007.04997*

- SEVEM: CMB map + 600 simulations
- Commander: CMB map + 100 simulations

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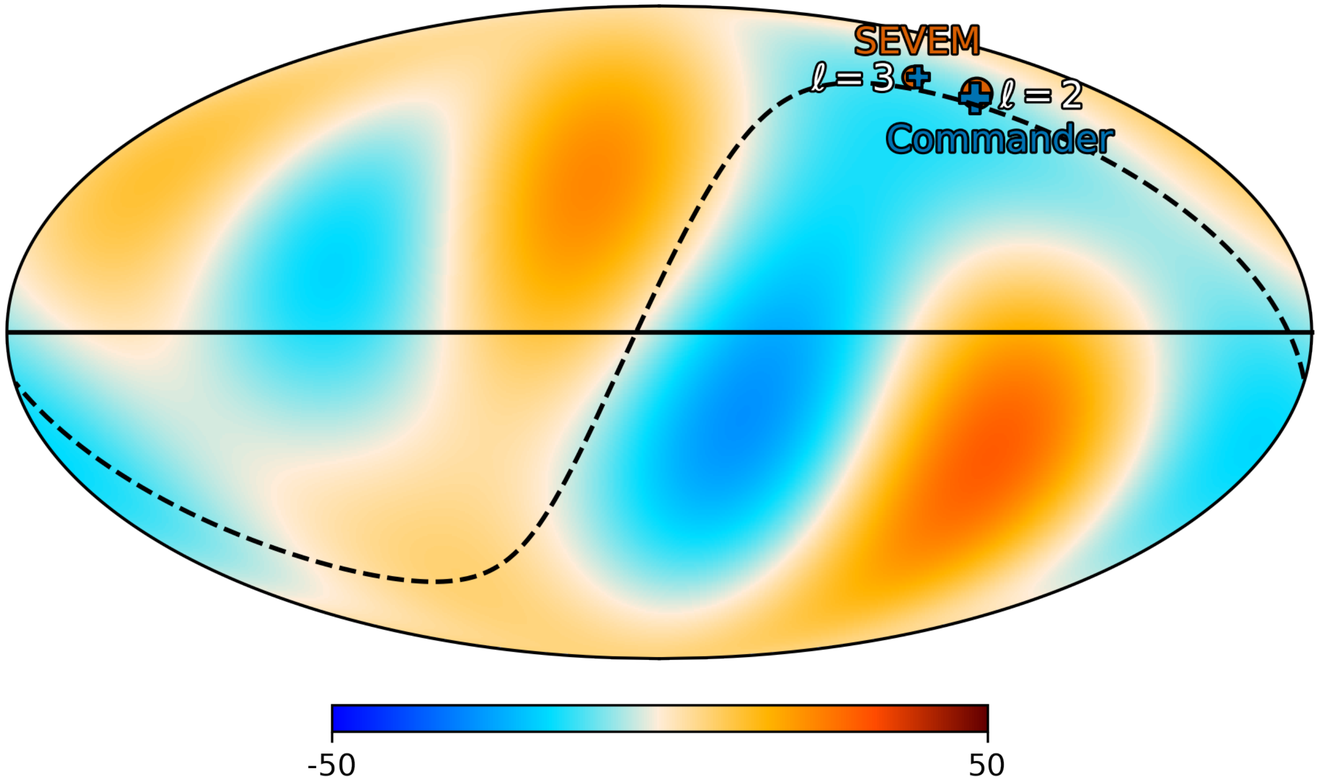
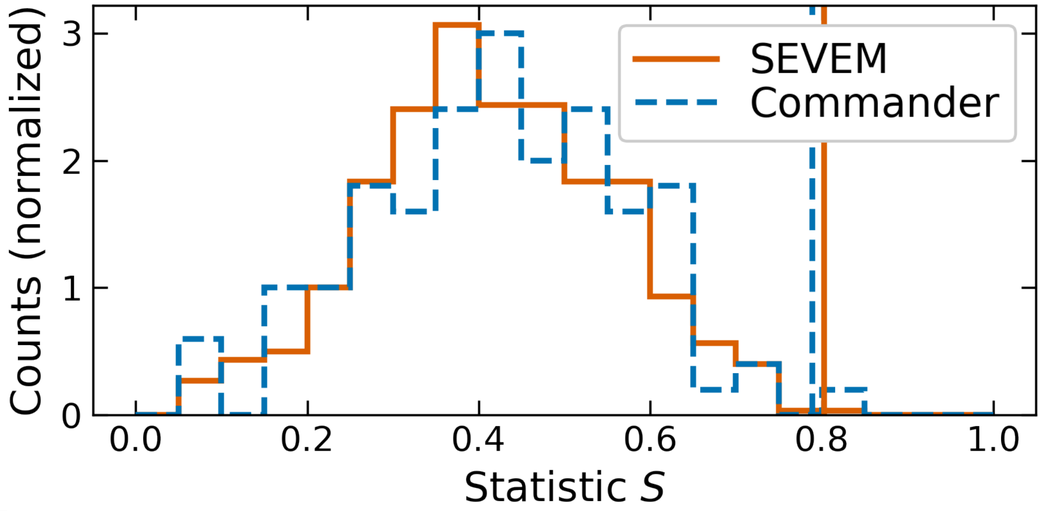
Example 1: **Quadrupole-Octopole Alignement**



Quadrupole + Octopole CMB map

- Preferred axis of each multipole determined using **multipole vectors**
- Similar directions for $\ell = 2$ and $\ell = 3$
- Statistic S measuring the level of alignement between the two multipoles



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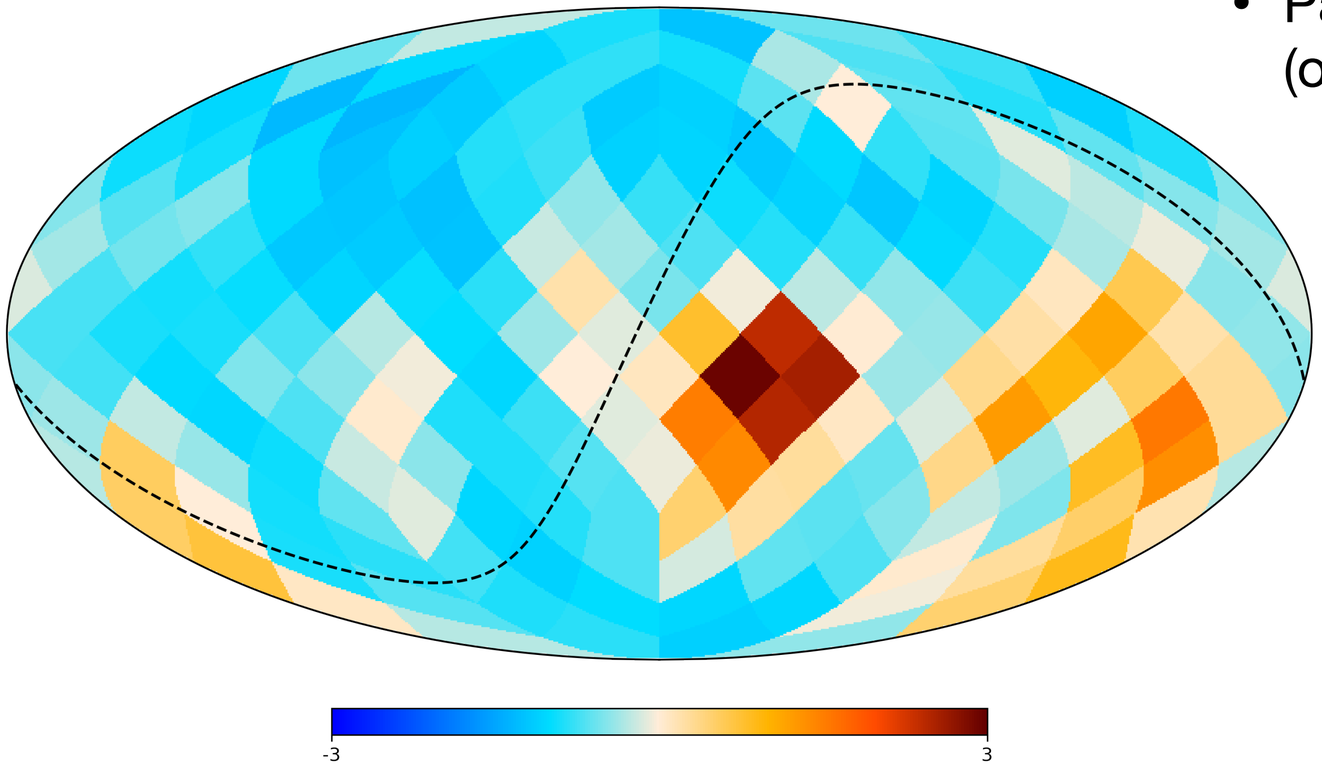
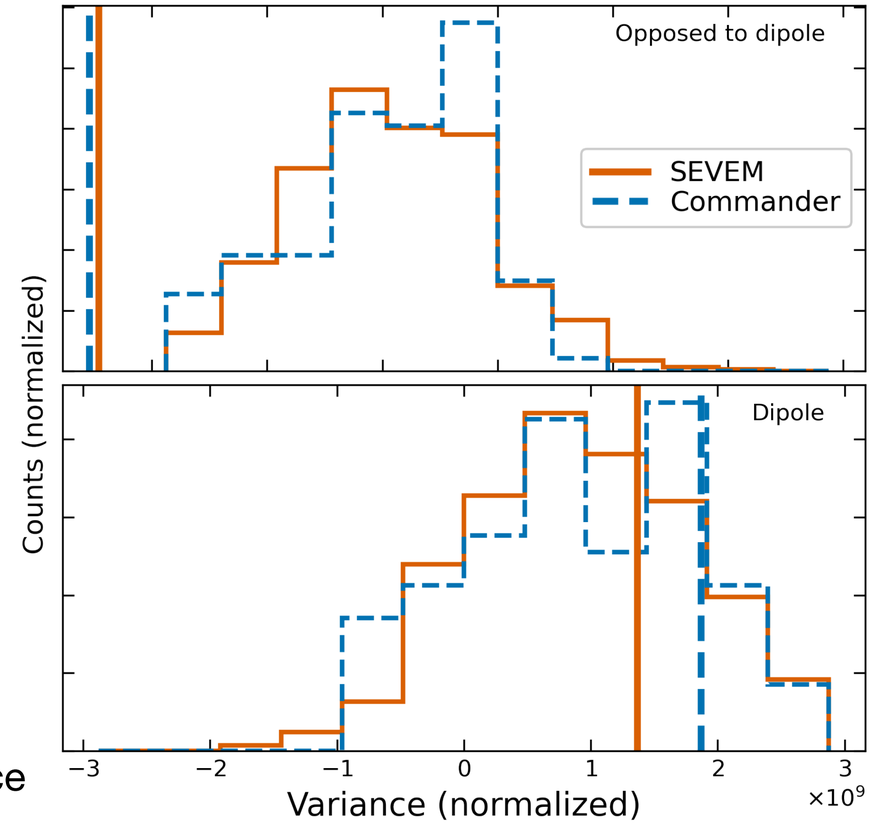
Example 2: **Hemispherical Asymmetry**



Observed **pixel variance** determined in **patches**

(subtracting the mean pixel variance from simulations)

- Large asymmetry between **northern/southern ecliptic hemispheres**
- Patch variance averaged over the Northern (opposed to dipole) hemisphere extremely low



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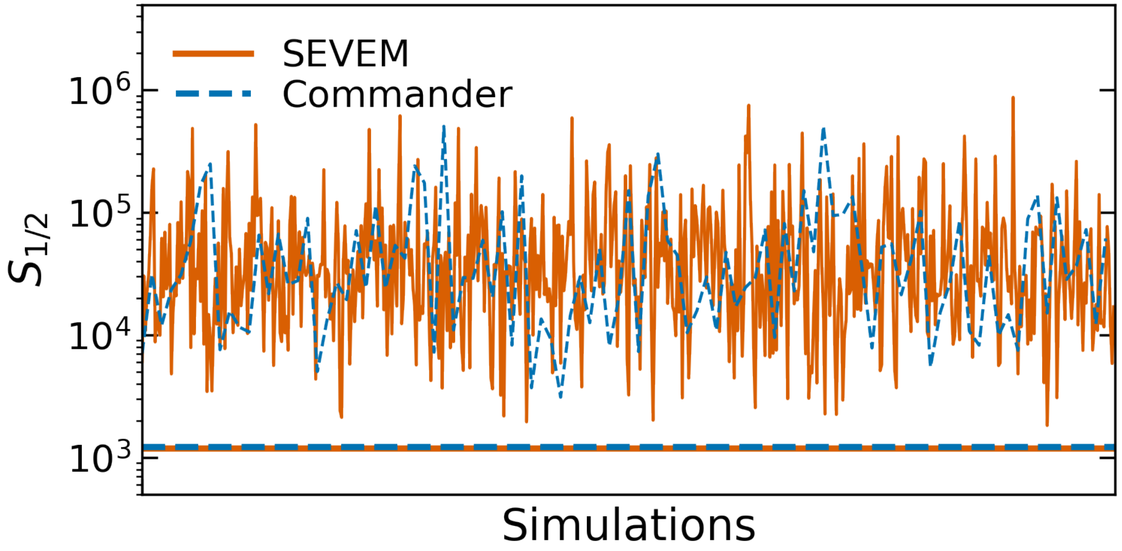
Example 3: **Lack of Correlation**

- Vanishing two-point angular correlation function $C(\theta)$ at large angular scales (> 60°)
- Characterised by the statistic:

$$S_{1/2} = \int_{-1}^{1/2} \mathrm{d}(\cos\theta)\,[C(\theta)]^2$$

- Lower observed value than in all simulations



SZ impact on CMB large scale anomalies

10^4 Gaussian CMB realizations + SZ from local Universe

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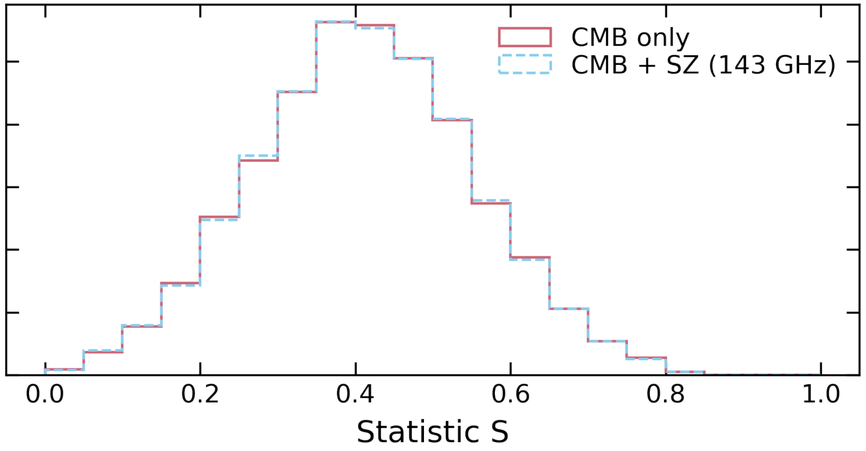
Quadrupole-Octopole Alignement



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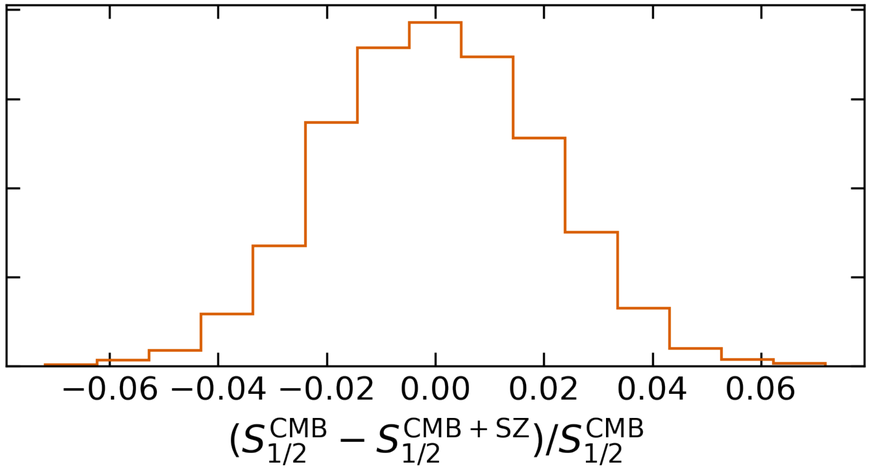
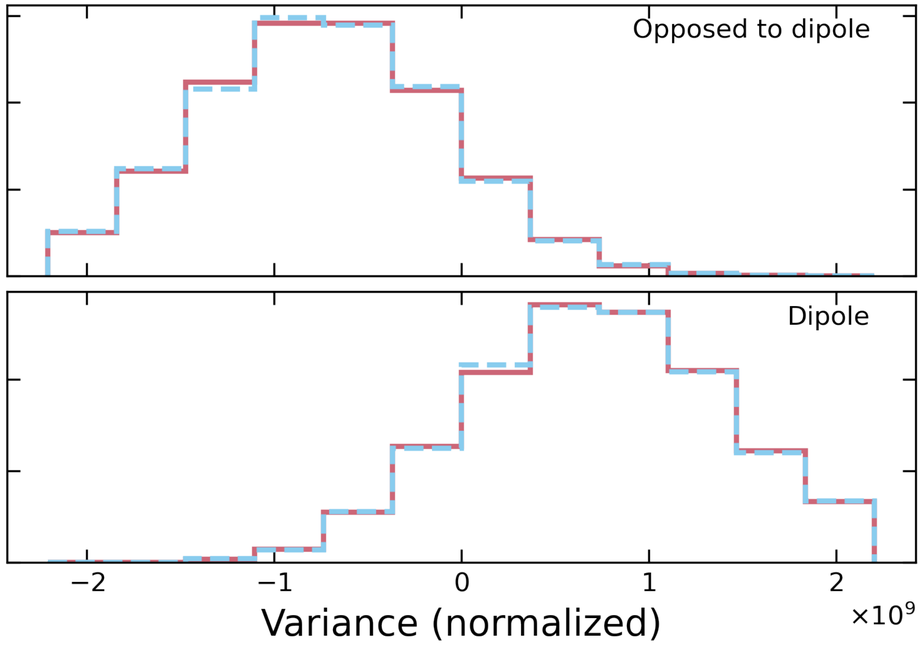


Hemispherical Asymmetry



⇒ **Negligible impact of the SZ emission from the local universe on every large-scale anomaly estimator tested**

Summary

- Re-analysis of the **CMB large-scale anomalies** in the Planck PR4 data
- New **high resolution simulated maps of the tSZ and kSZ signals from the Local universe**
- No hint of correlation between CMB and Local universe tSZ and kSZ on large scales
- On-going analyses: comparisons of individual objects (e.g. Virgo cluster) with observations

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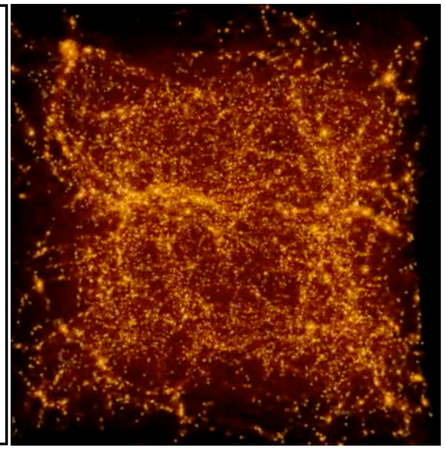
LOCALIZATION simulation *(Sorce et al)*

- Constrained initial conditions
- Higher resolution (2048^3)
- Run with the RAMSES code
- Ready in the coming months



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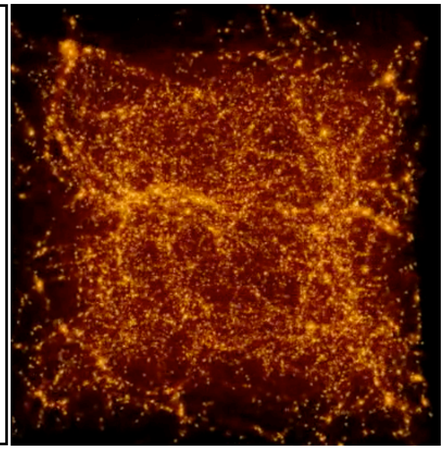

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Thanks!