Cosmoverse, Napoli
May, 2025

A new >5sigma tension: Why are the CMB fluctuations much colder than expected around galactic dark matter halos?

Frode K. Hansen

Based on work in collaboration with D. Garcia Lambas, H. Luparello, F. Toscano, L. Pereyra, A. Ruiz et al.

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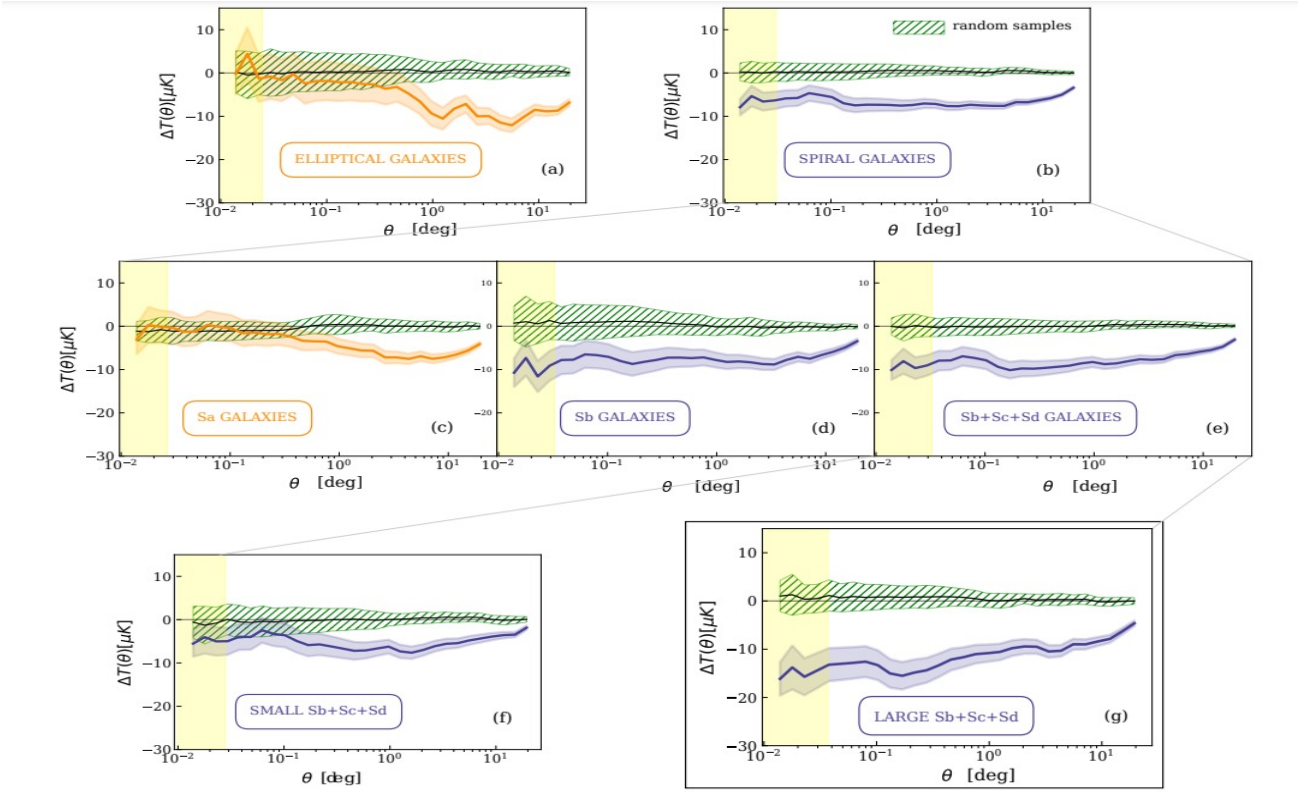
There’s something weird going on in the local Universe

Based on work in collaboration with D. Garcia Lambas, H. Luparello, F. Toscano, L. Pereyra, A. Ruiz et al.

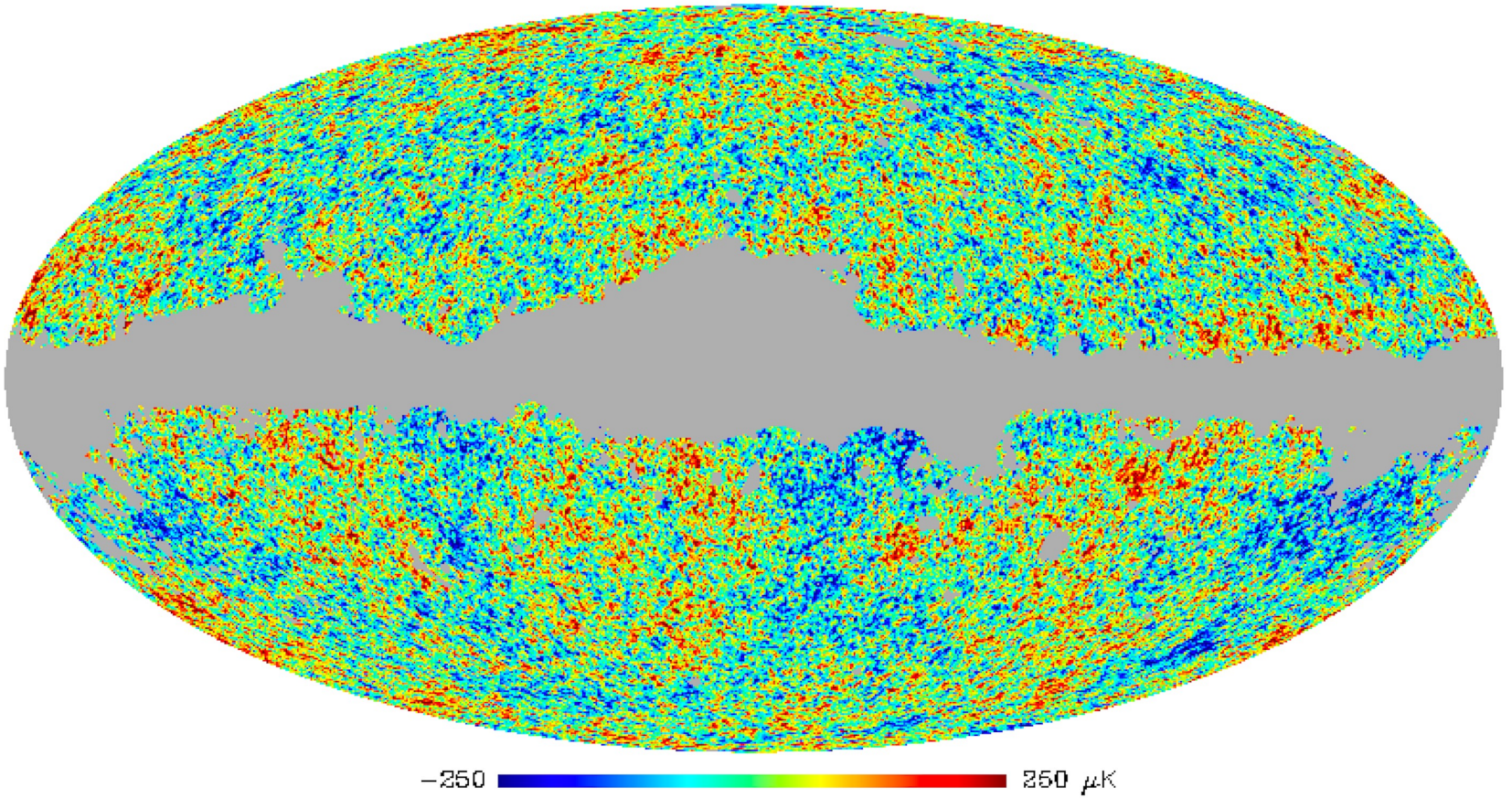
Serendipitous discovery of a new extragalactic foreground associated to late-type galaxies.

Luparello et al. 2023



Planck Collaboration, 2020, Planck Results 2018 IV, A&A, 641, A4

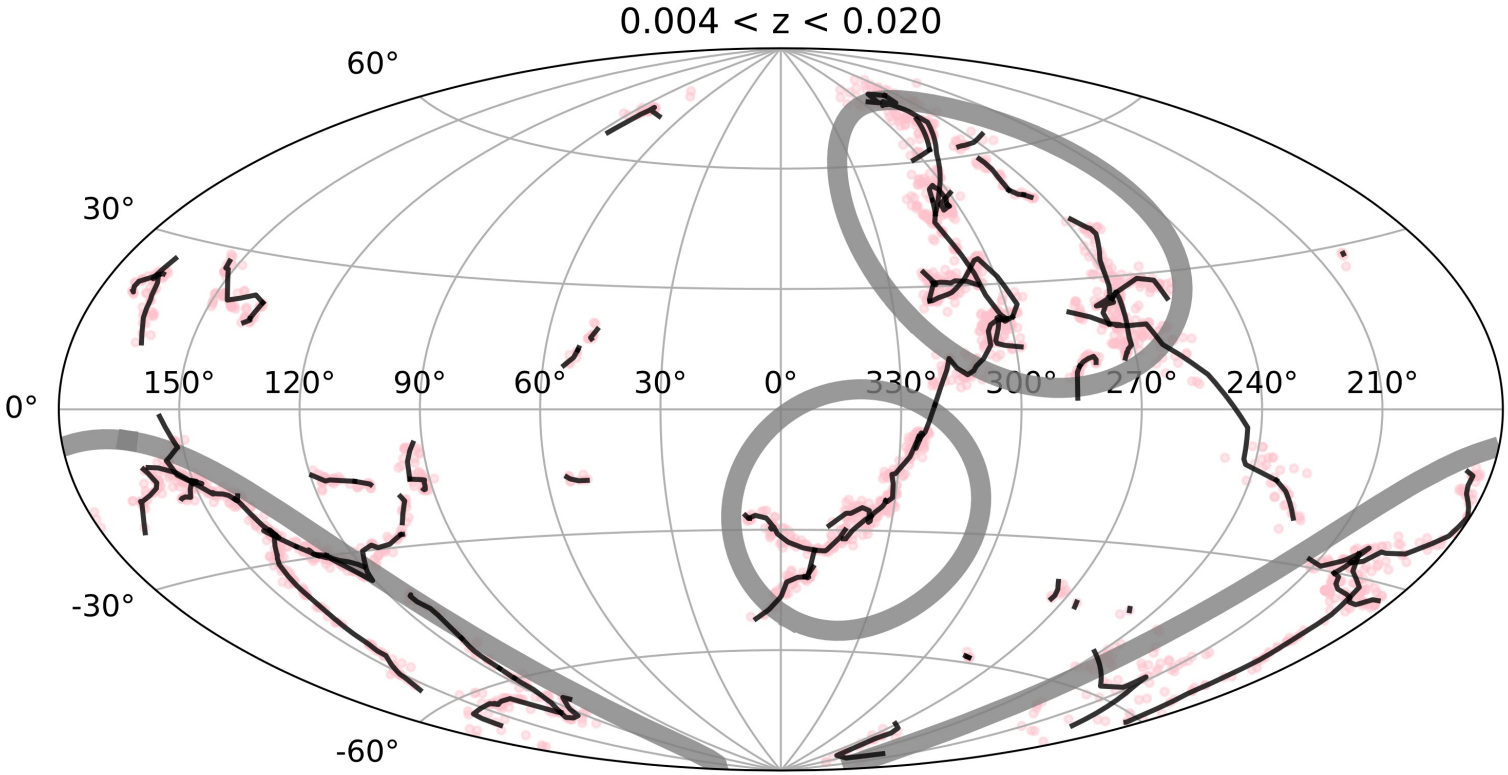
Planck Smica MAP



Huchra et al. 2012, ApJS, 199, 2

2MRS Redshift Survey

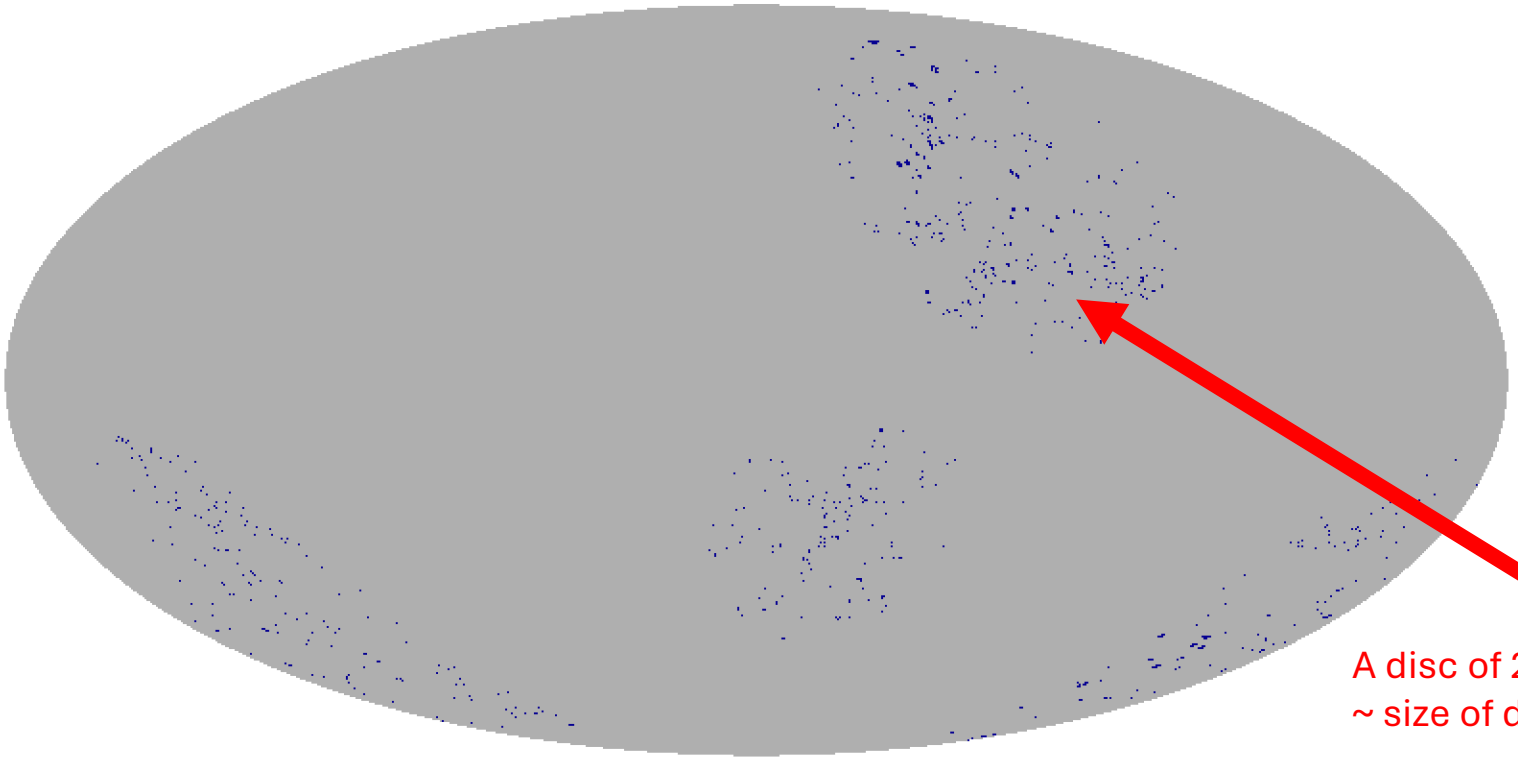
Most massive filaments in $0.004 < z < 0.02$



Huchra et al. 2012, ApJS, 199, 2

2MRS Redshift Survey

Large late type spiral galaxies $0.004 < z < 0.02$

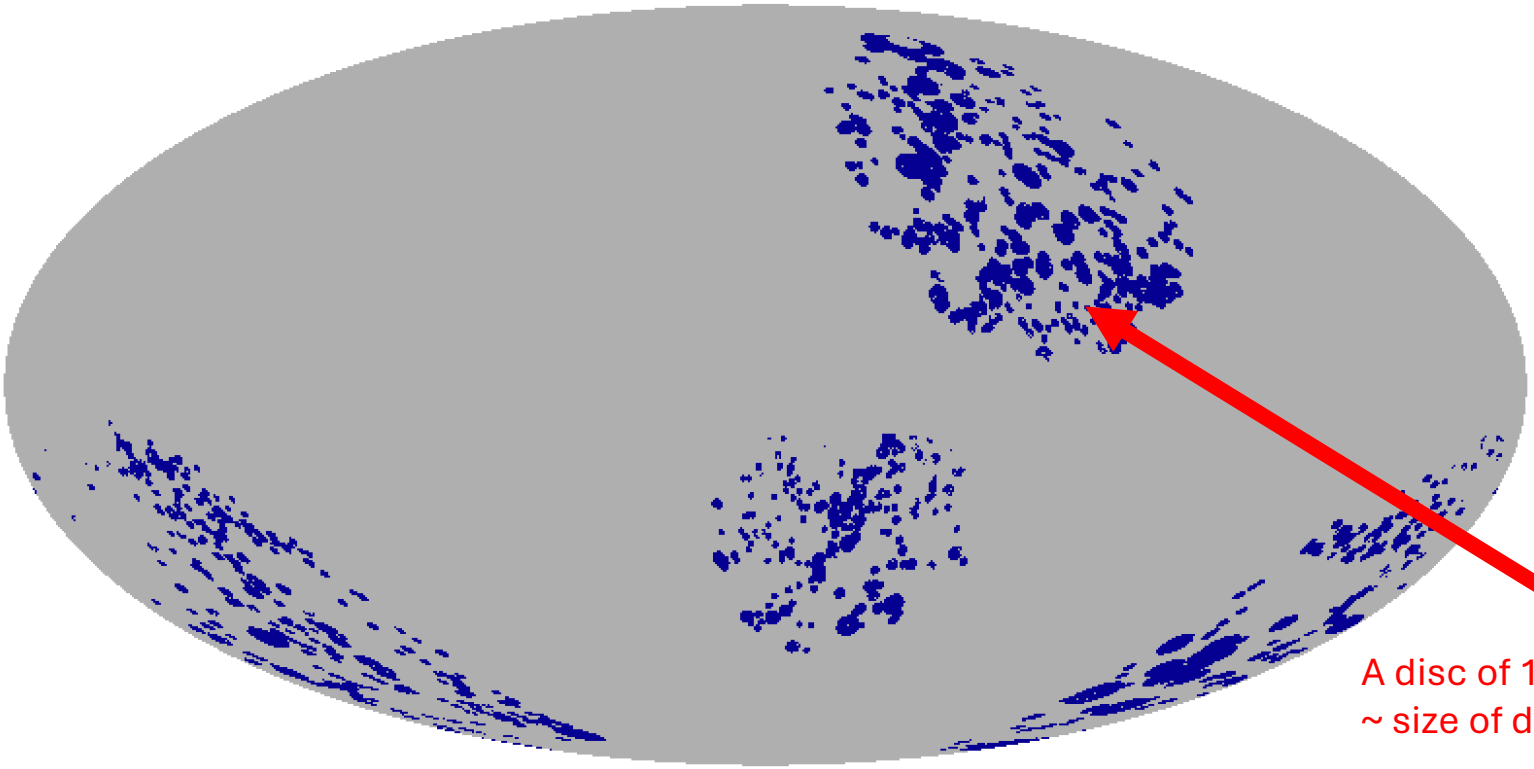


A disc of 200 kpc for each galaxy
~ size of dark matter halo

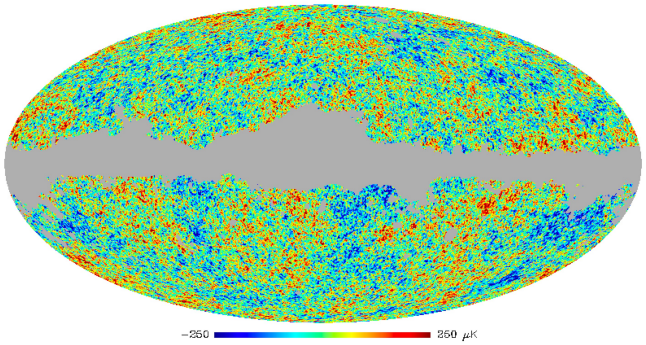
Huchra et al. 2012, ApJS, 199, 2

2MRS Redshift Survey

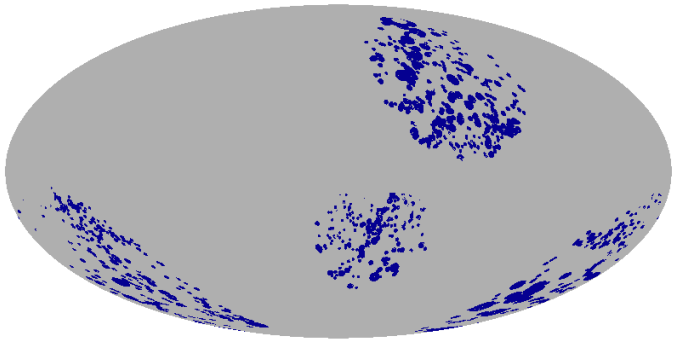
Large late type spiral galaxies $0.004 < z < 0.02$



A disc of 1Mpc for each galaxy
~ size of dark matter halo



X



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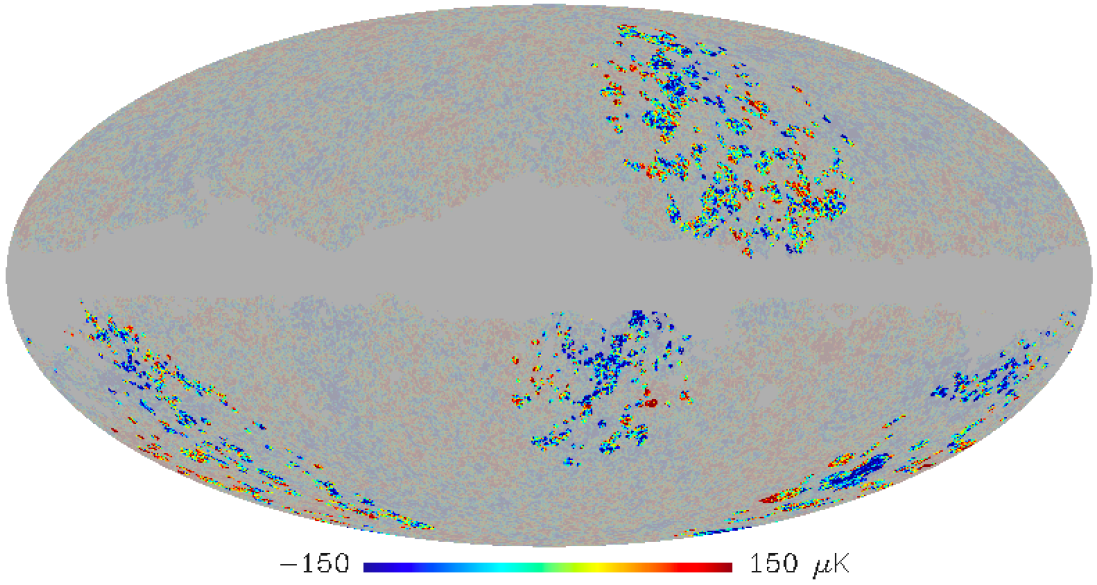
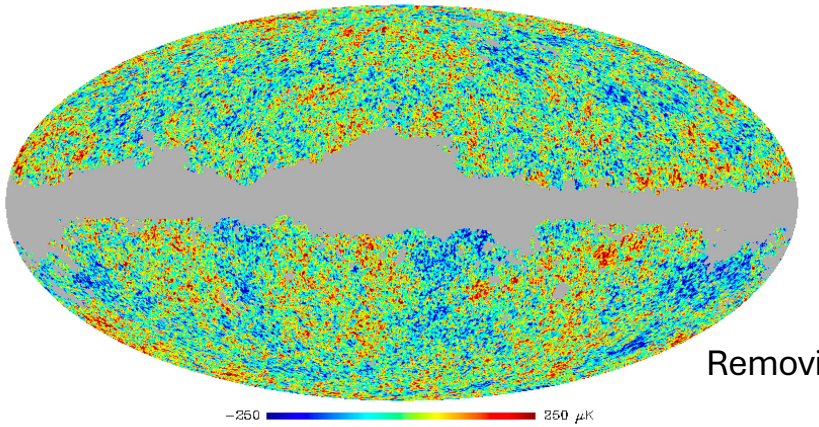
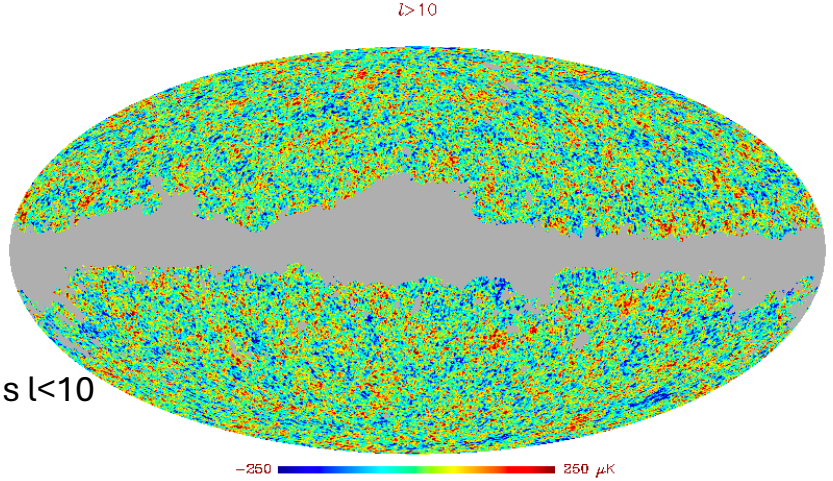
CMB temperature in nearby galactic filaments



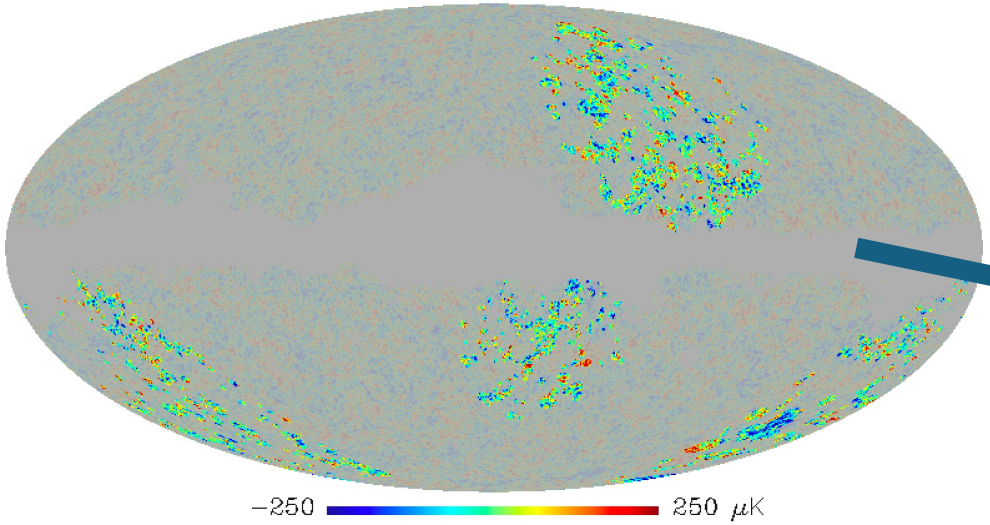
Planck map



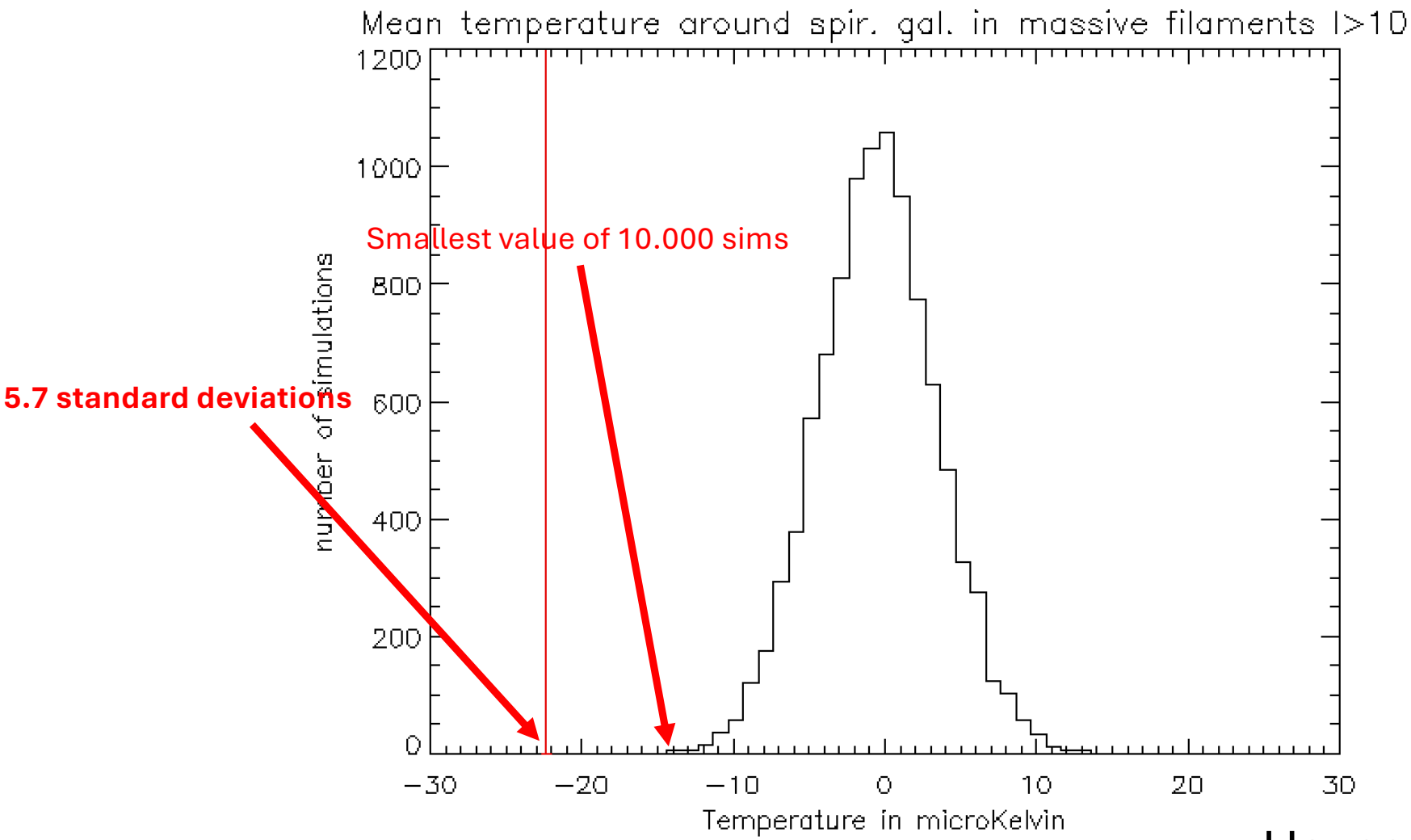
Planck map with largest scales (l ≤ 10) removed



Removing the largest scale fluctuations l<10

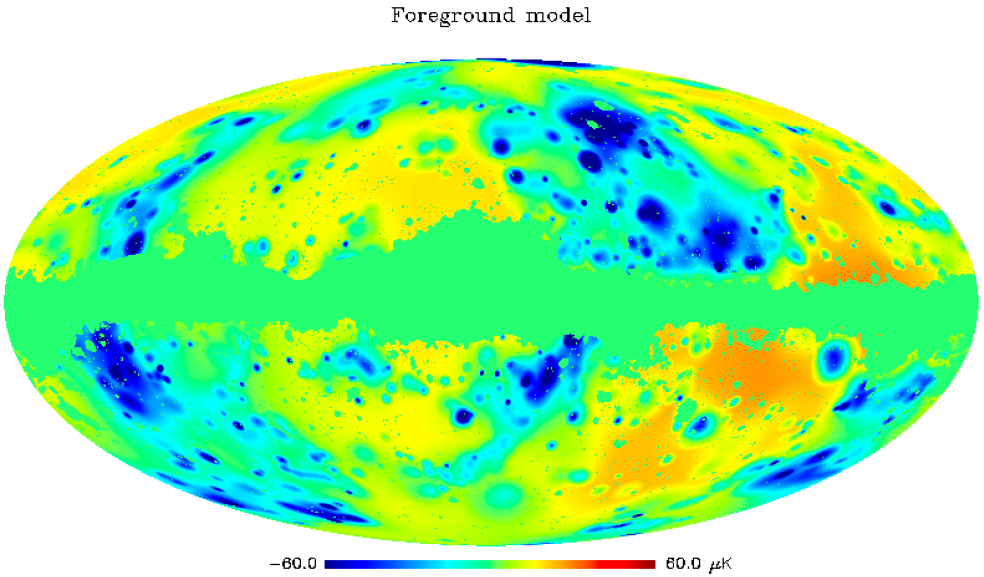


Mean temperature of CMB over area with Galaxies = -22.5 μK

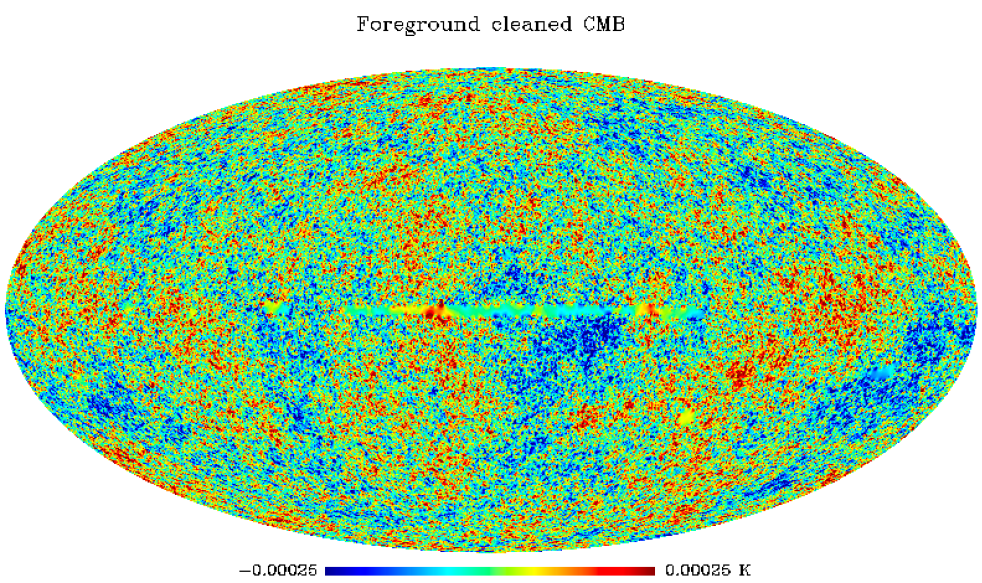


Hansen et al. 2025

The mean temperature of the CMB in the areas of the sky which coincide with nearby galaxies is **5.7σ away** from the temperature found in CMB simulations based on ΛCDM



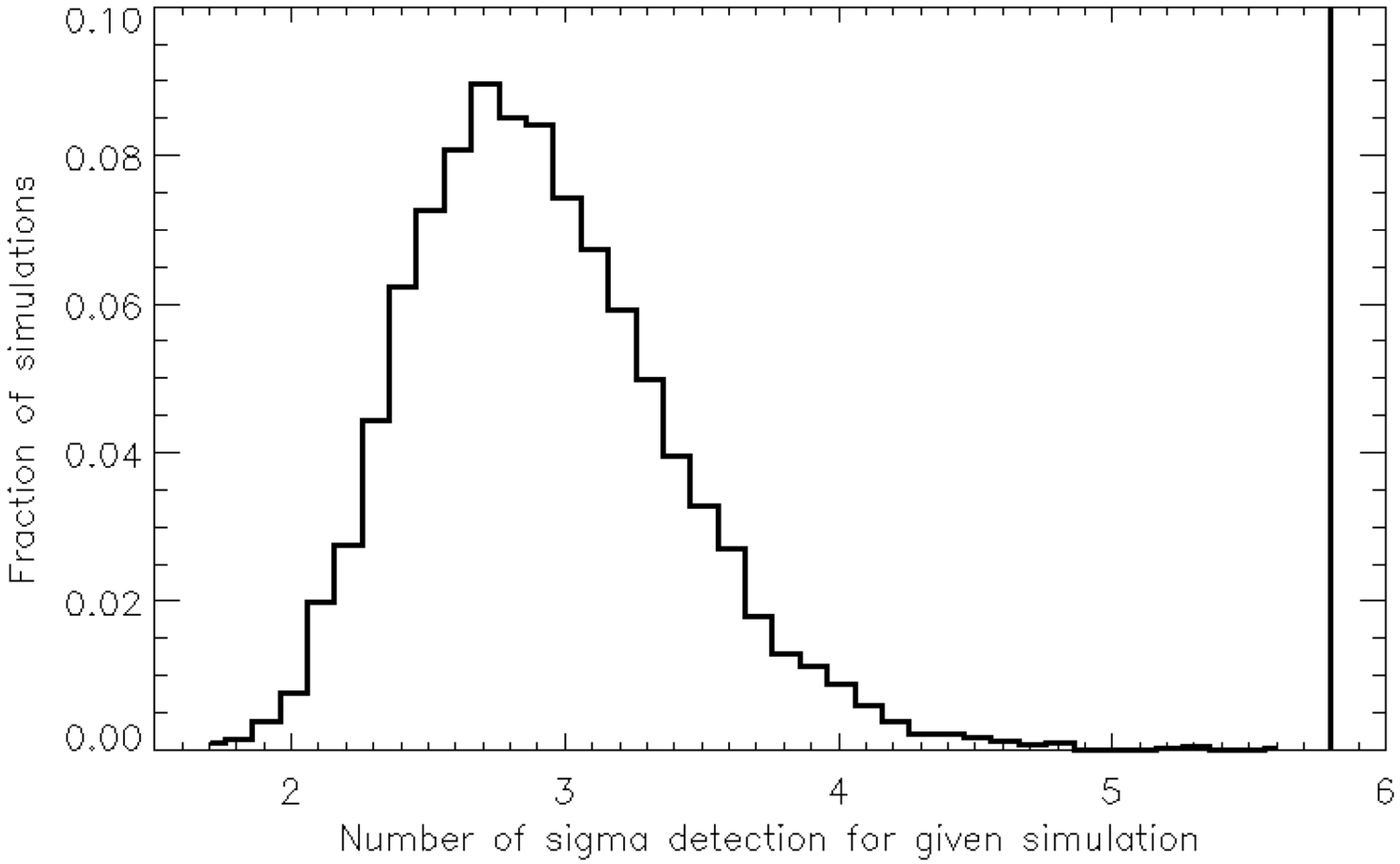
Galaxy distribution
(simple model of the effect)



Does this affect cosmological Parameter estimates from CMB???
NO!
(Toscano et al. 2025)

Look-elsewhere-effect?

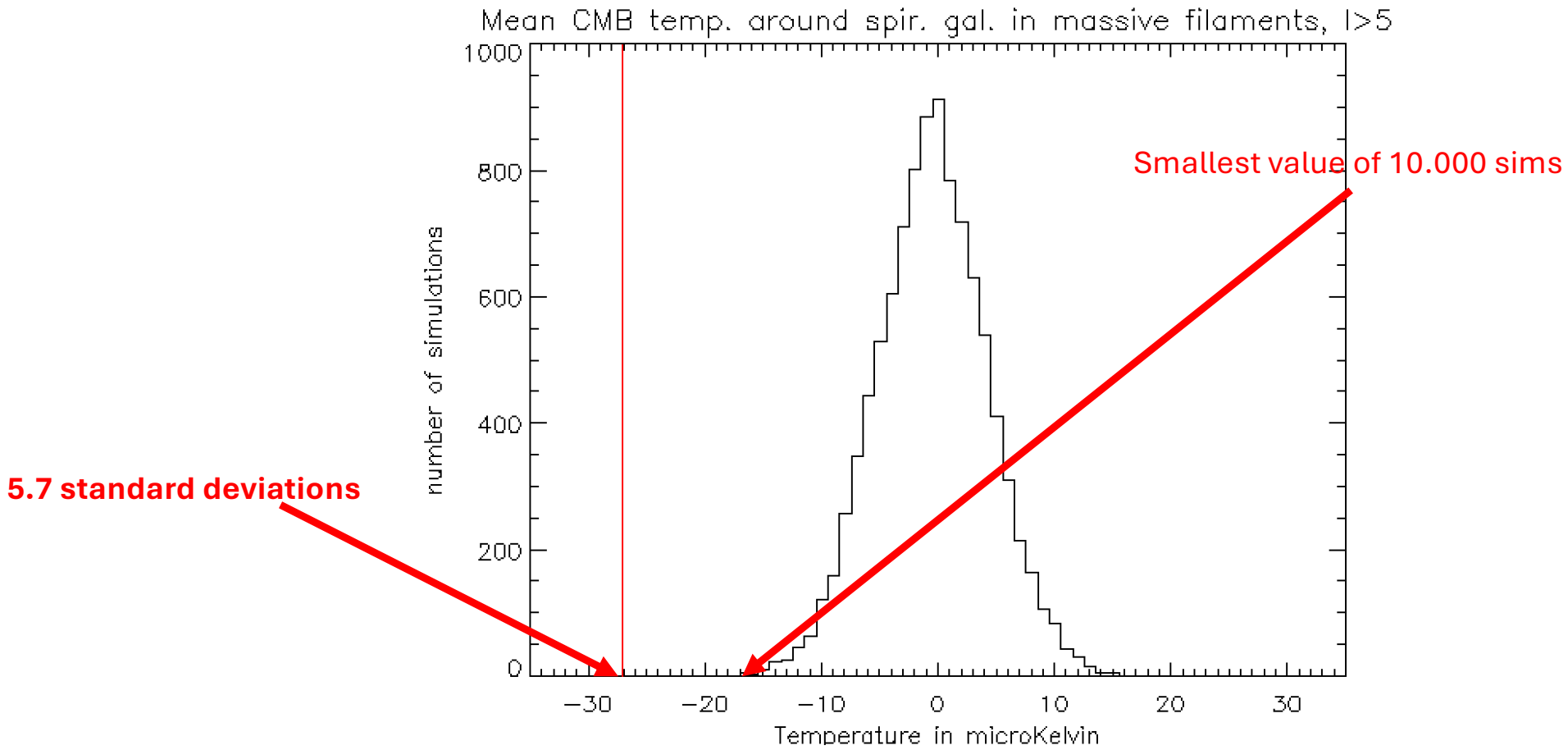
Tweaking the parameters optimally for each simulation, the detection is still **p < 0.0001**



Systematic effect??

Frequency dependence

- From WMAP 44GHz to Planck 217GHz



Frequency dependence

Hansen et al. 2025

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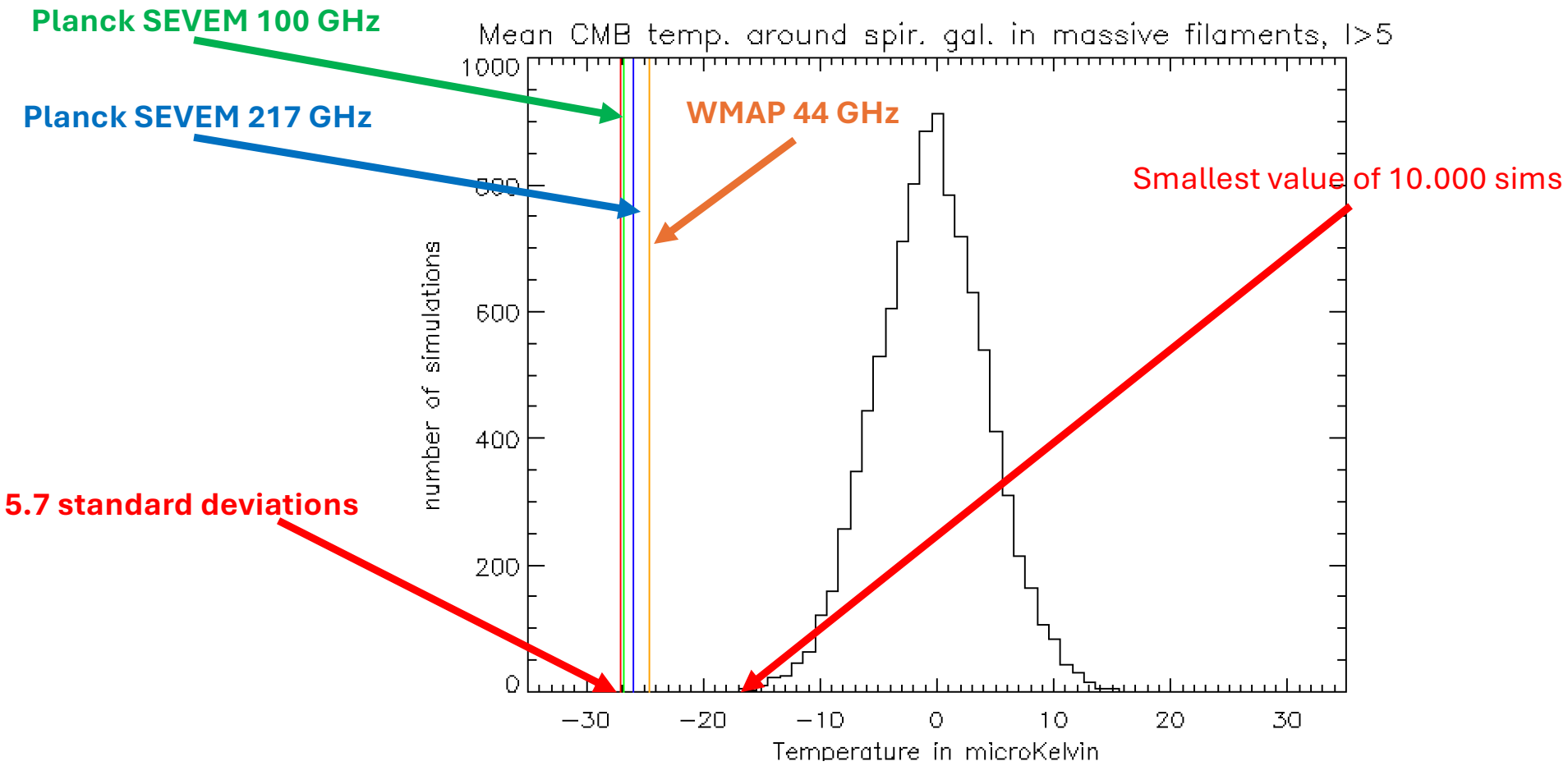
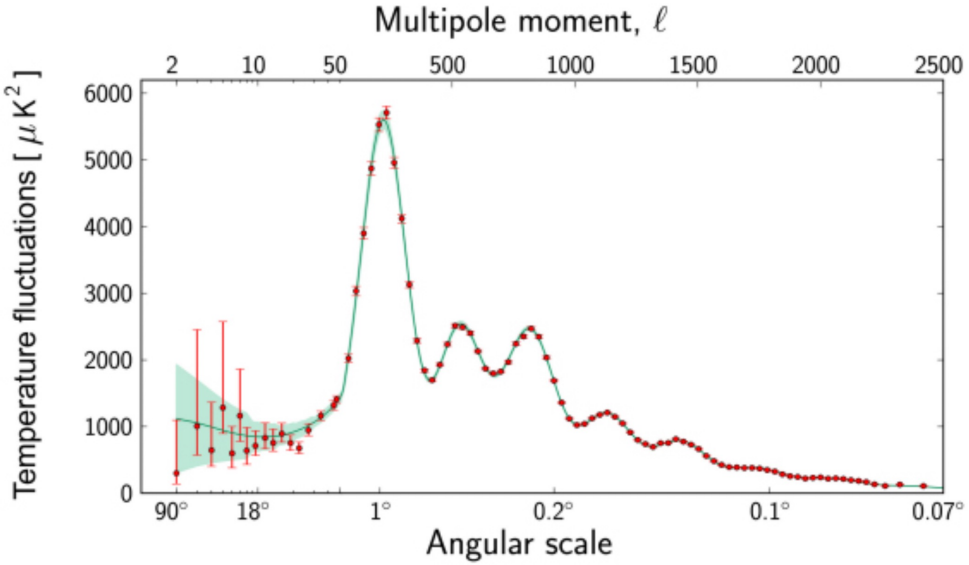


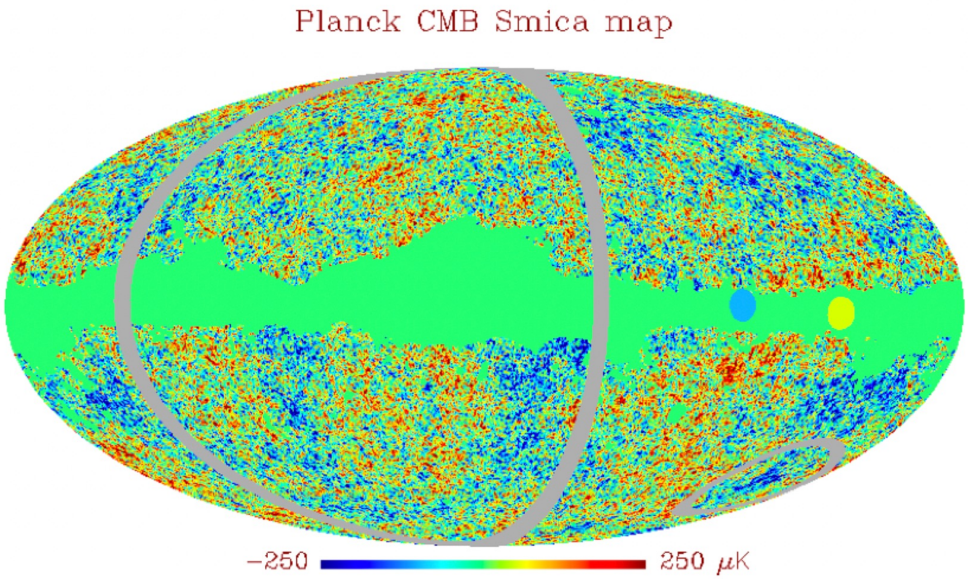
The cooling of CMB photons in the galactic halos seems to preserve the black-body spectrum of the CMB

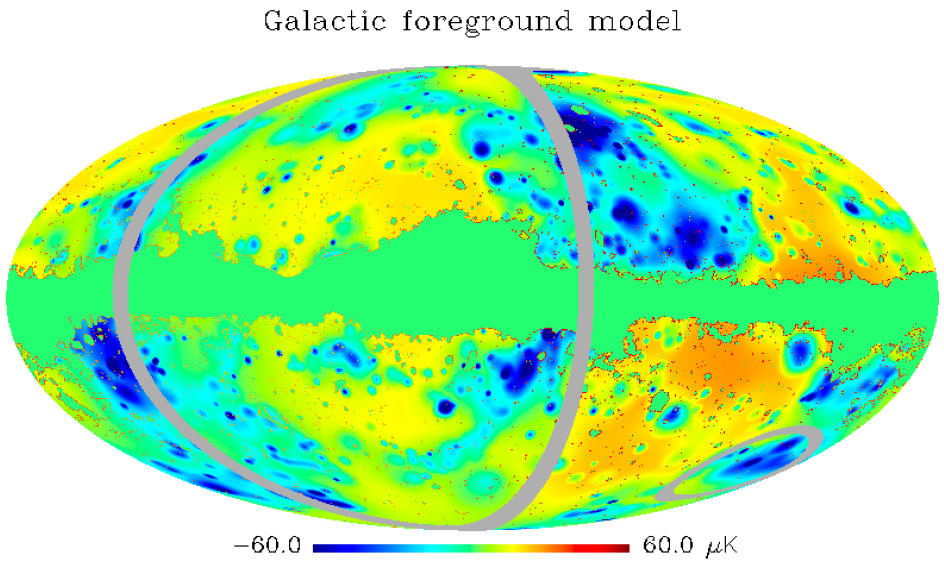
CMB anomalies

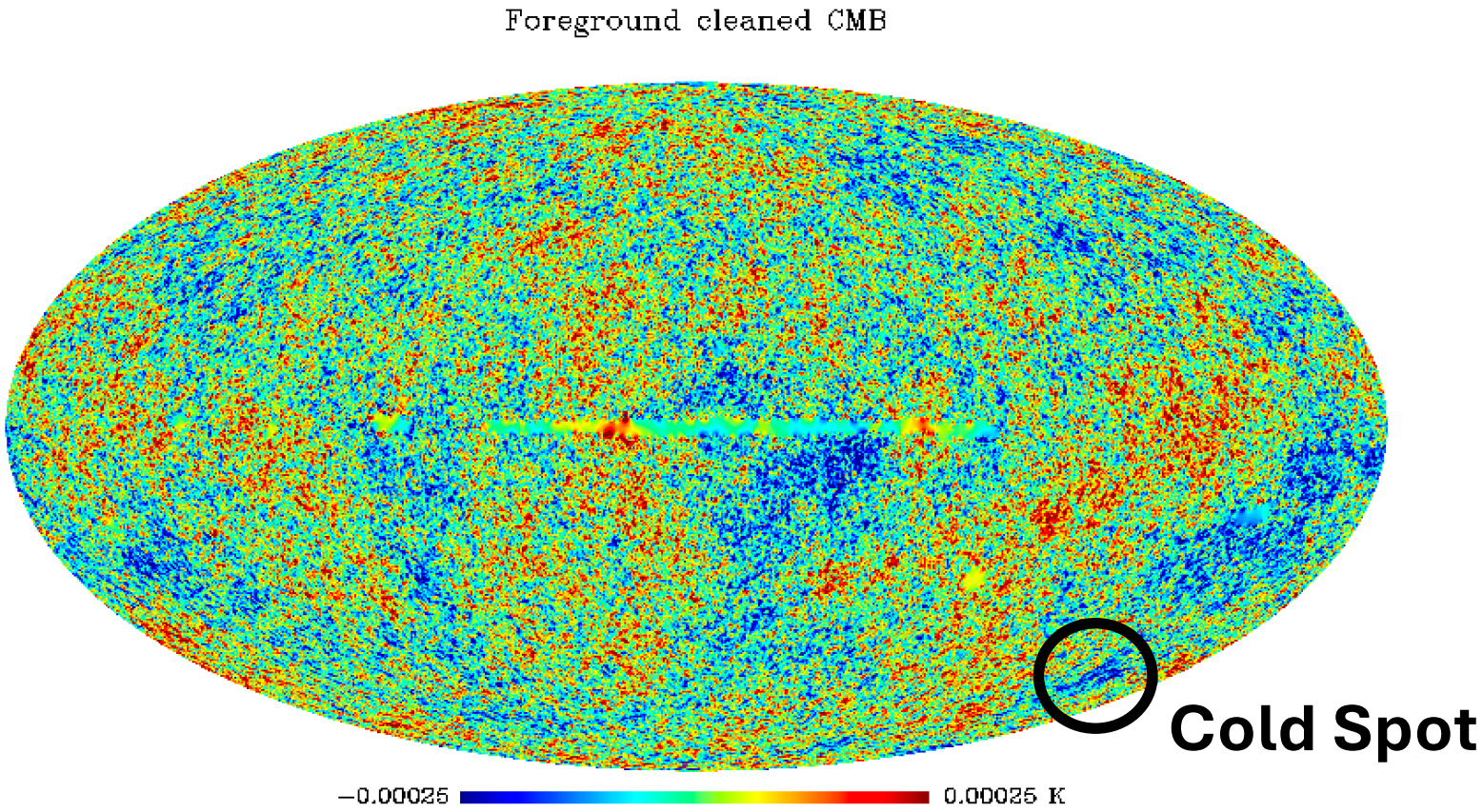


- **Low quadrupole**
- **Generally low power for l<40**
- **Unexpected couplings between the lowest multipoles**
- **Hemispherical asymmetry:** more fluctuation power in one hemisphere than in the opposite hemisphere. **Extends over a larger range of angular scales.**
- **The non-Gaussian CMB cold spot**

Hemispherical asymmetry



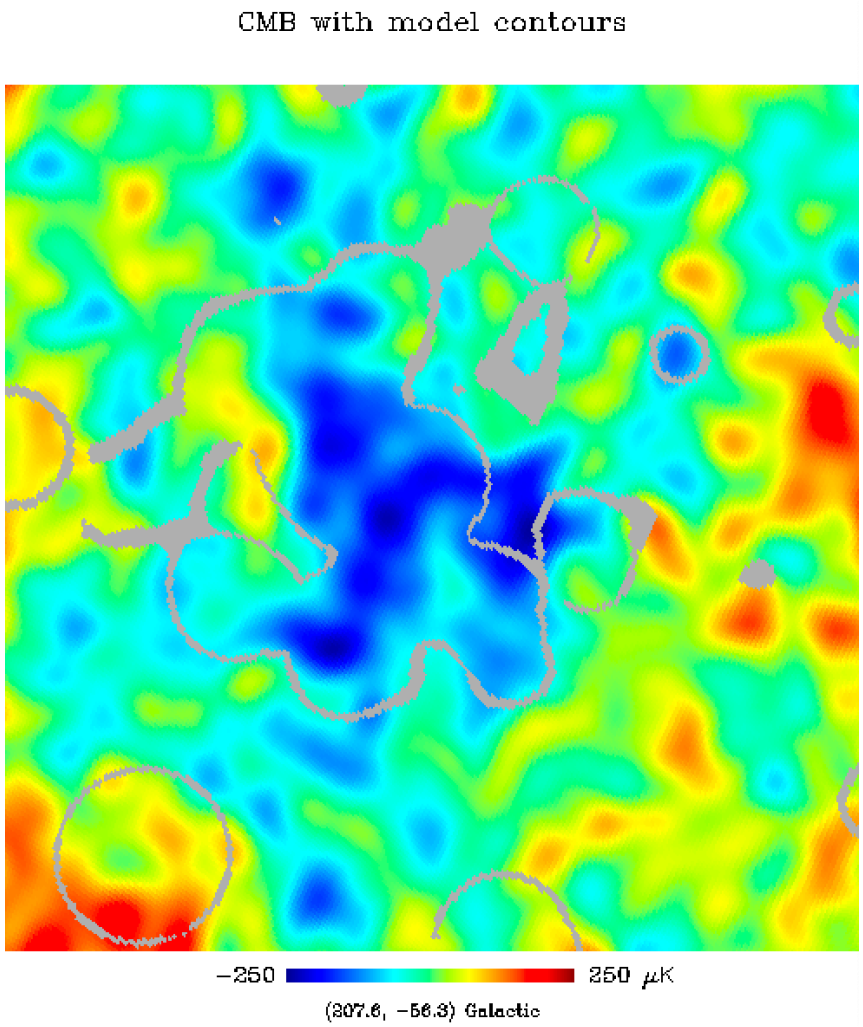


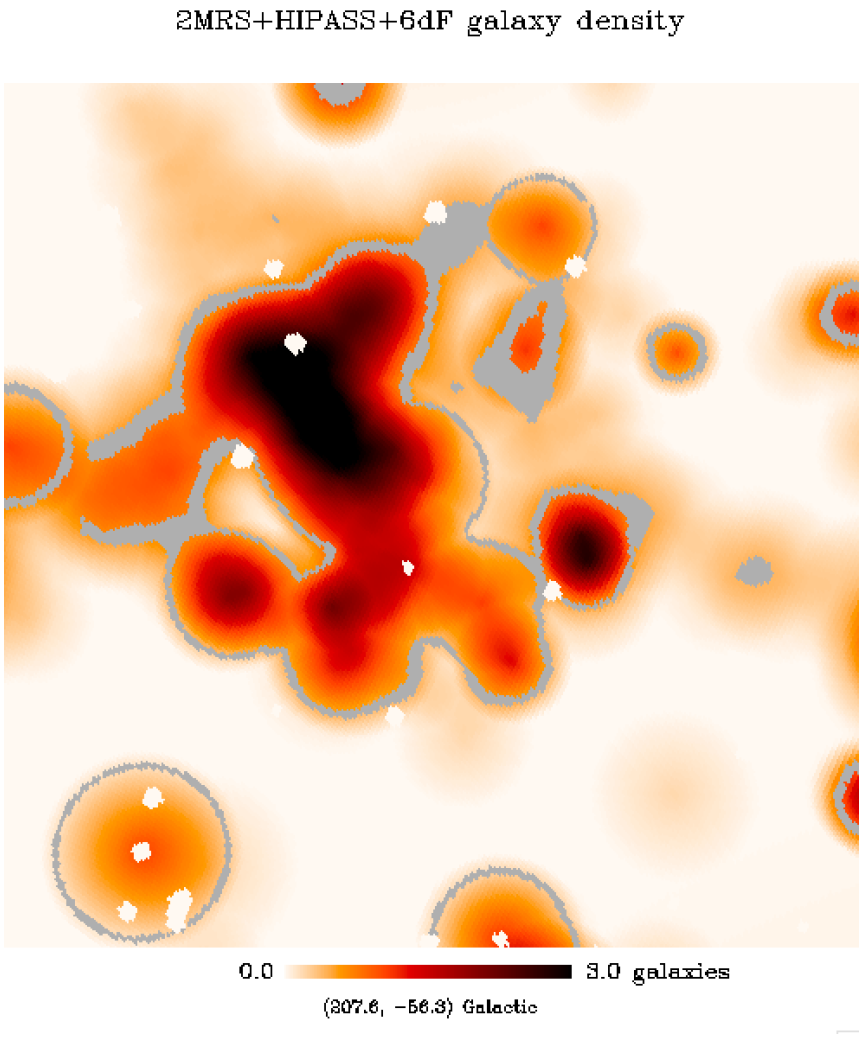


A non-Gaussian cold spot (Vielva et al. 2004)

Explanation in terms of ISW effect from large void has been proposed, but does not seem viable.

From Garcia Lambas et al. 2024





Hard to explain in terms of

- Systematics
- Statistical fluctuation


It’s only another 5 sigma.
Could be a coincidence
ΛCDM is still working well!
ΛCDM is still fine!

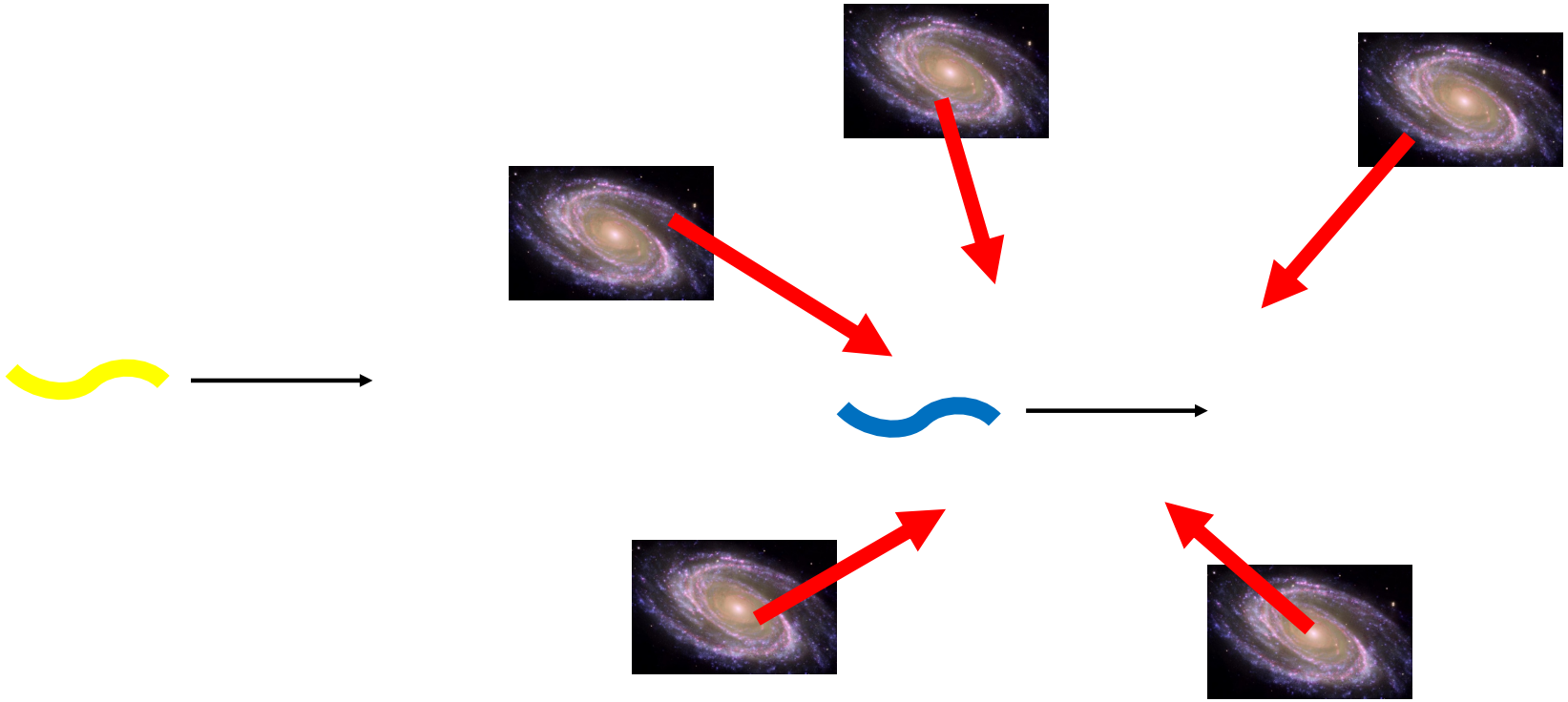
Which physical process can be behind?

- What about the SZ effect? → **Far too small in this area and frequency dependence is not consistent**
- Angular extension is similar to galactic dark matter halos**: Are we seeing some interaction with dark matter particles?**
- Spiral galaxies and dense galactic environments: Is the **magnetic field** of importance here? What about the frequency dependence? **Axions**? **frequency independence??**
- Is the high density environment itself important? **Chamelions**?
- What else? Which process can preserve black body??

What about Rees-Sciama/ISW effects?

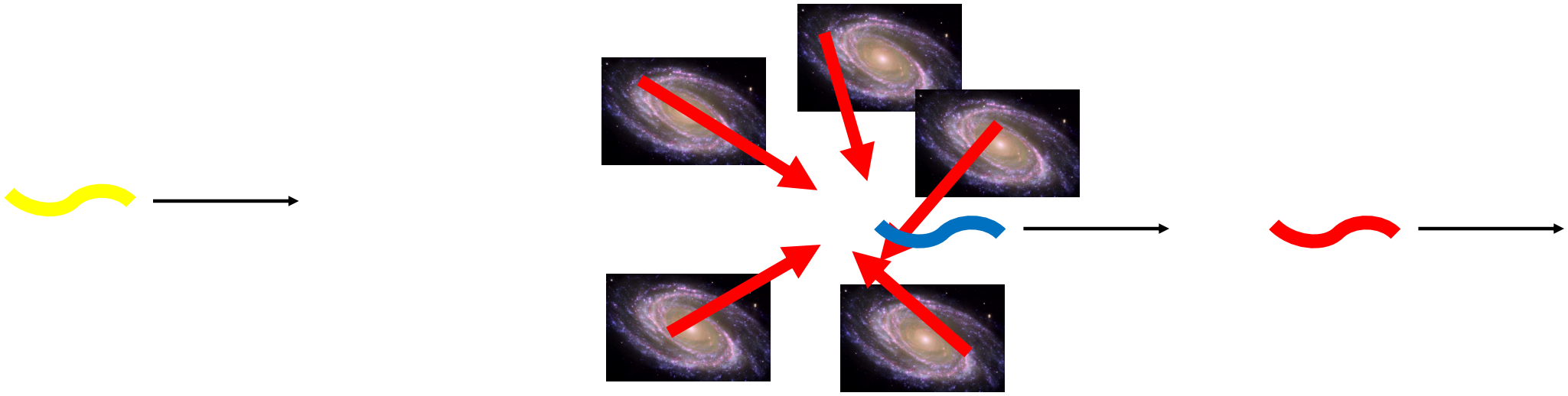
- Frequency independent
- Rees-Sciama effect should give colder CMB photons in overdensities
- ISW effect with cosmological constant should give the opposite, hot CMB photons in overdensities and cold in voids

Rees-Sciama effect



Non-linear growth

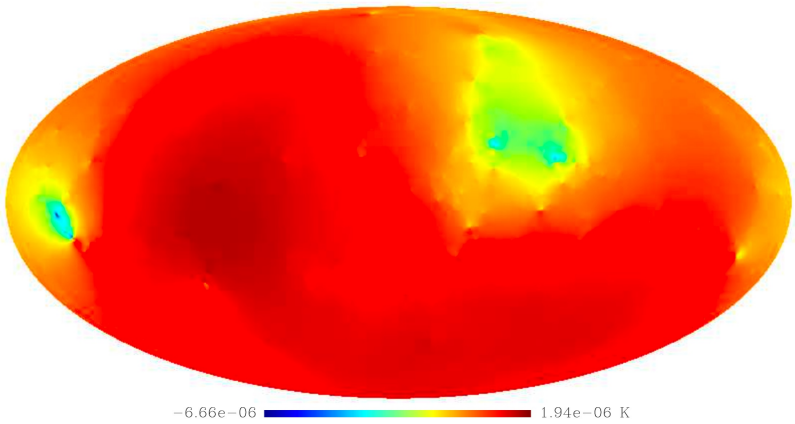
Rees-Sciama effect



CMB photons are cooled in overdensities

Frequency independent!!!

Rees-Sciama effect



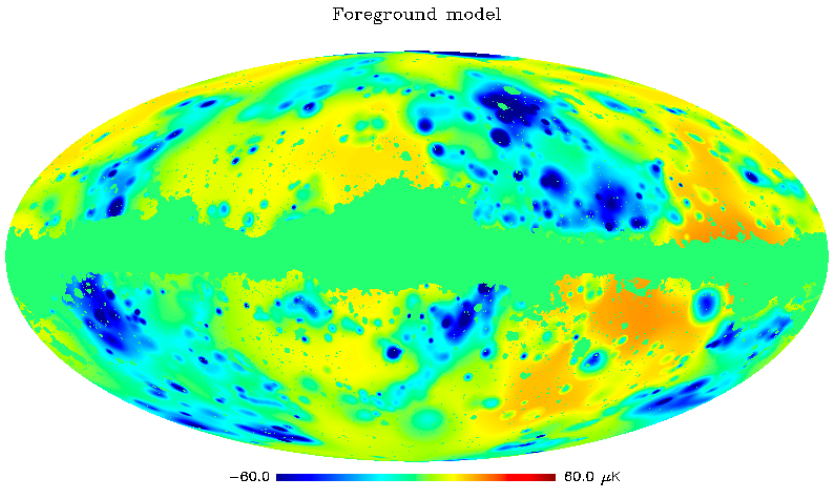
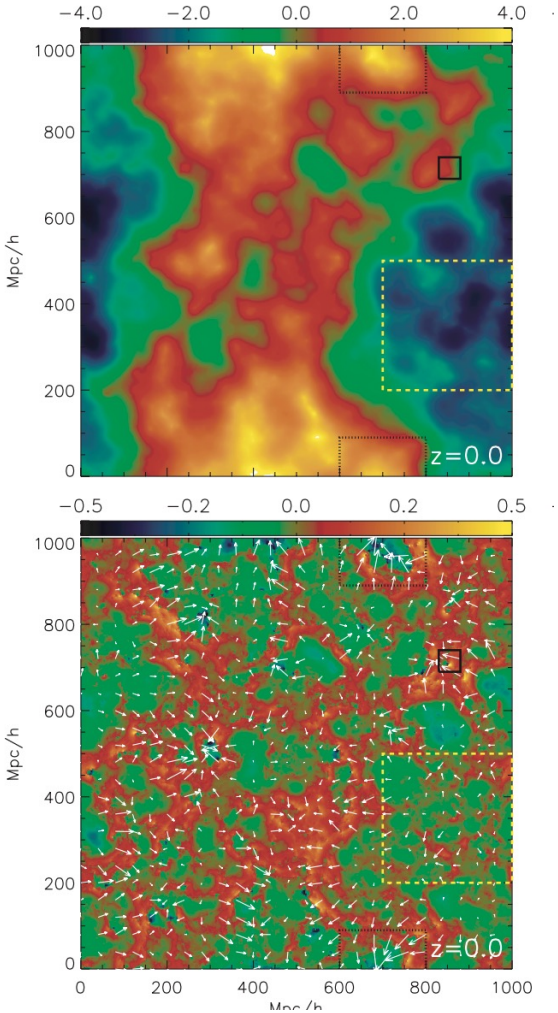


Figure from **M. Maturi et al. 2007**

What about Rees-Sciama/ISW effects?

- Frequency independent
- Rees-Sciama effect should give colder CMB photons in overdensities
- ISW effect with cosmological constant should give the opposite, hot CMB photons in overdensities and cold in voids A larger effect!!!

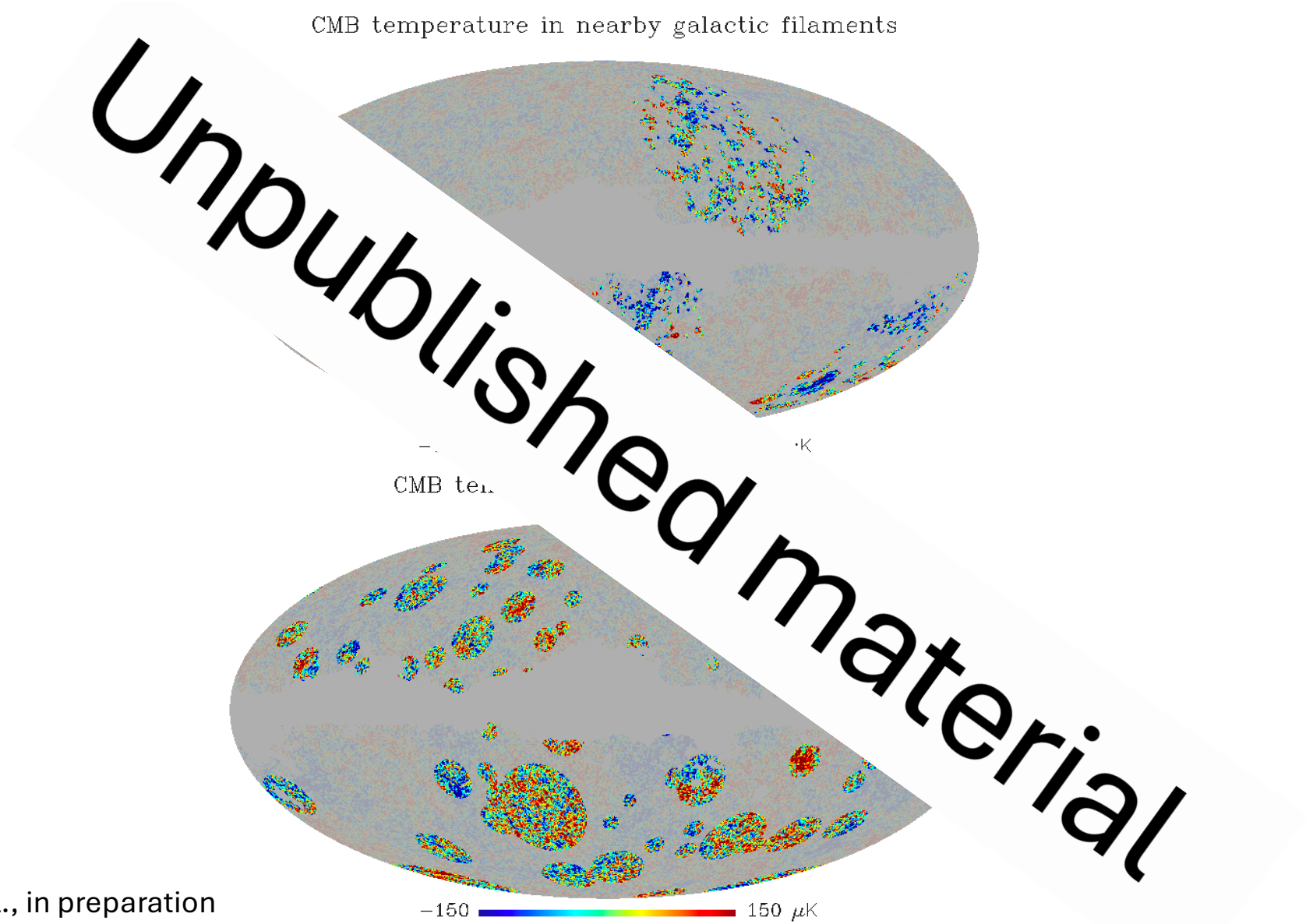
ISW and RS effect out to 100Mpc at z=0
Figure from
Cai et al. 2010



We should see hot CMB photons in galaxies
...AND...
cold CMB photons in voids!!!

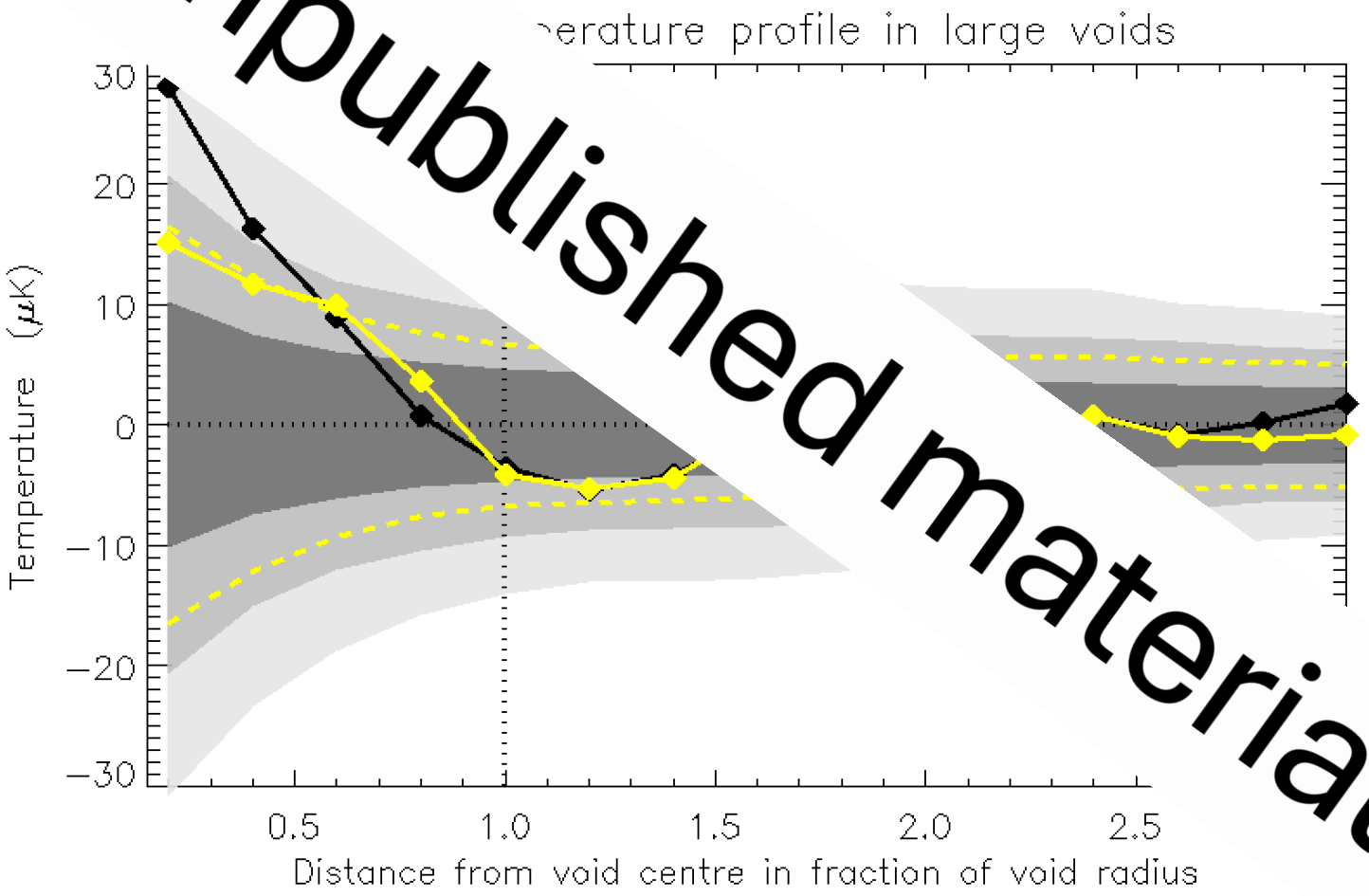
Has been detected several times for z>0.1

What about the nearby voids??

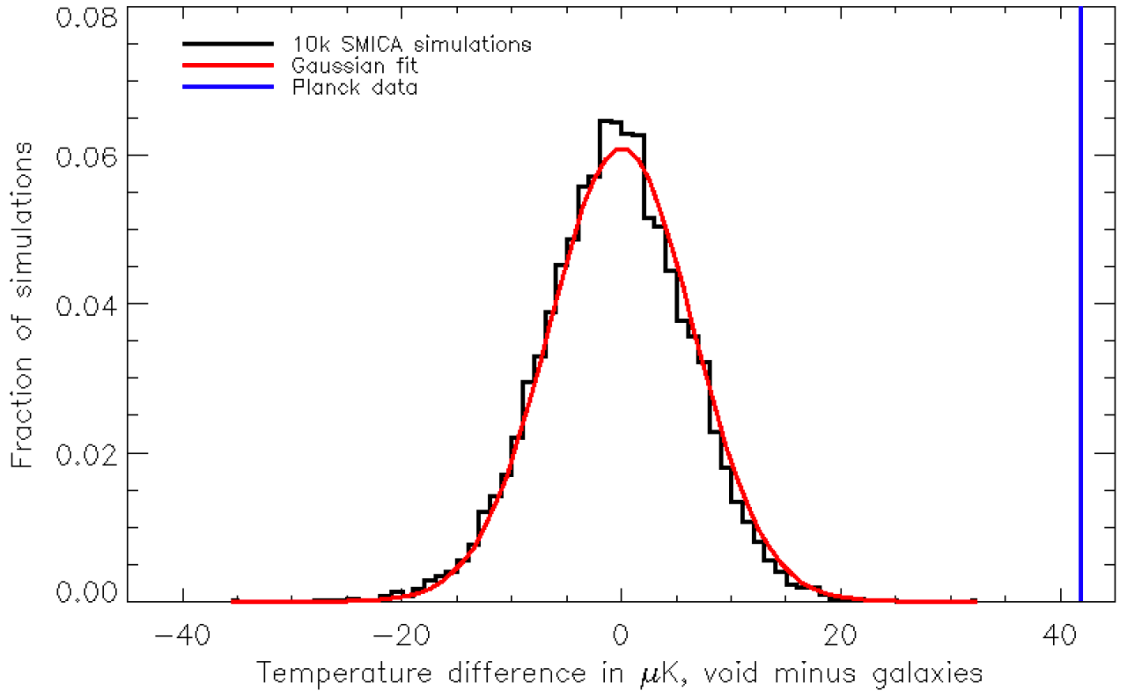


Hansen et al., in preparation

mperature in nearby voids



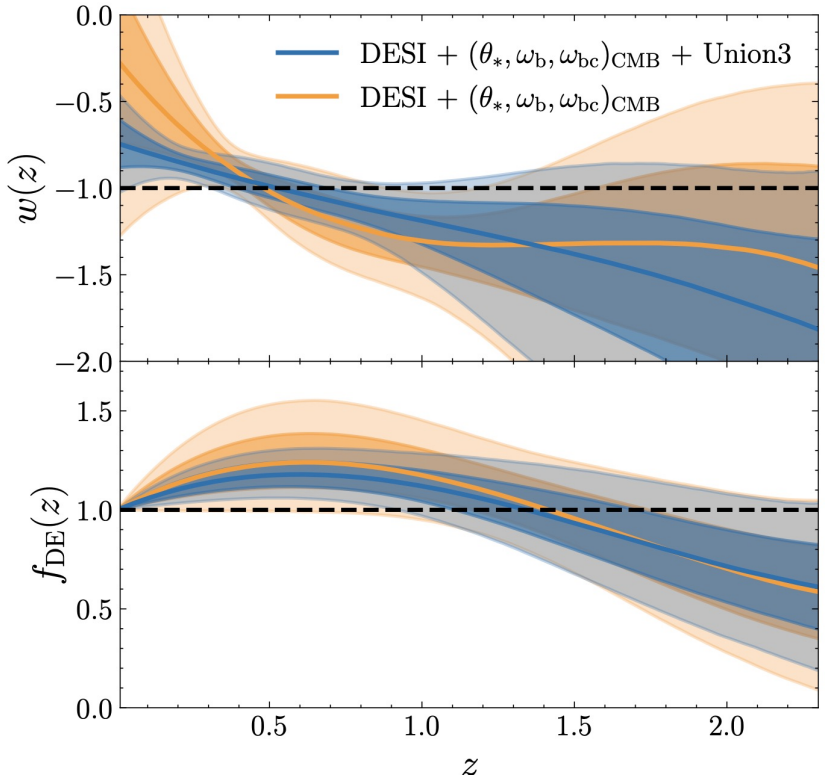
Temperature in overdensities minus temperature in voids: **6.5 sigma deviation**



- Cold CMB photons in overdensities
- Hot CMB photons in voids

Has the ISW changed sign in the very recent universe???

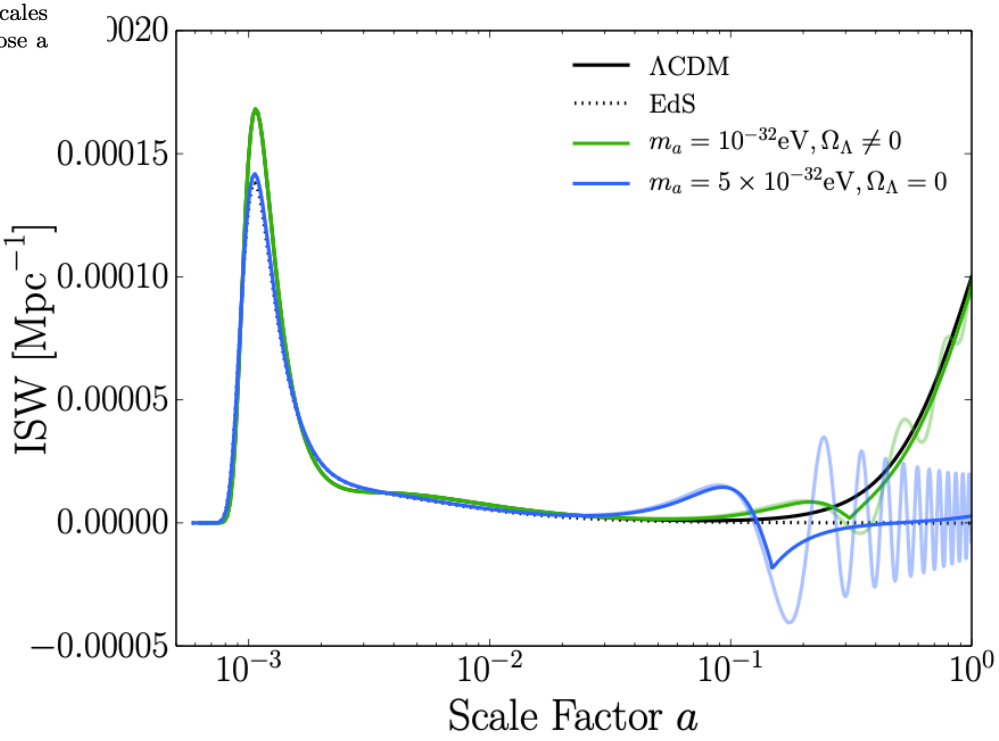
DESI results, Figure from Lodha et al. 2025



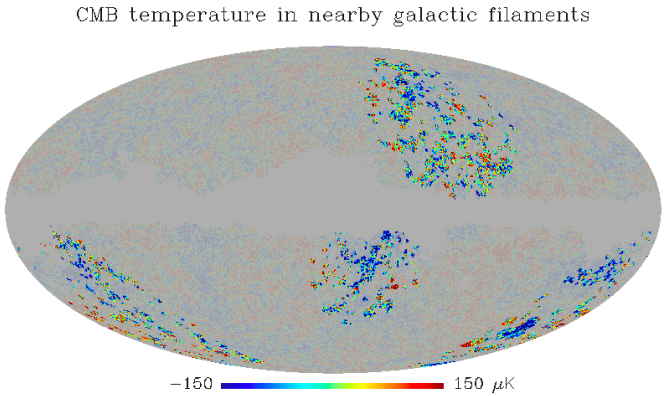
A search for ultralight axions using precision cosmological data (2017)

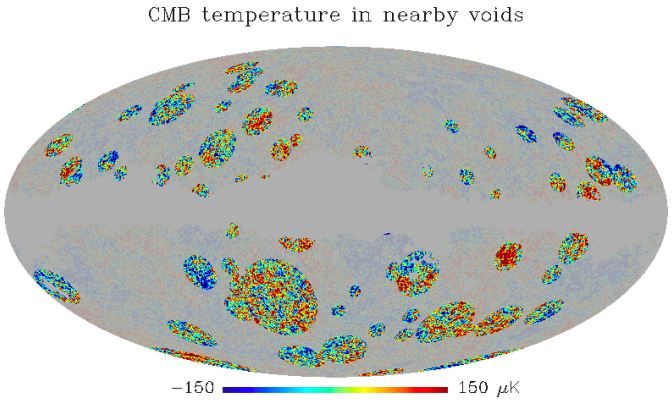
Renée Hlozek,[1] Daniel Grin,[2] David J. E. Marsh,[3,*] and Pedro G. Ferreira[4]

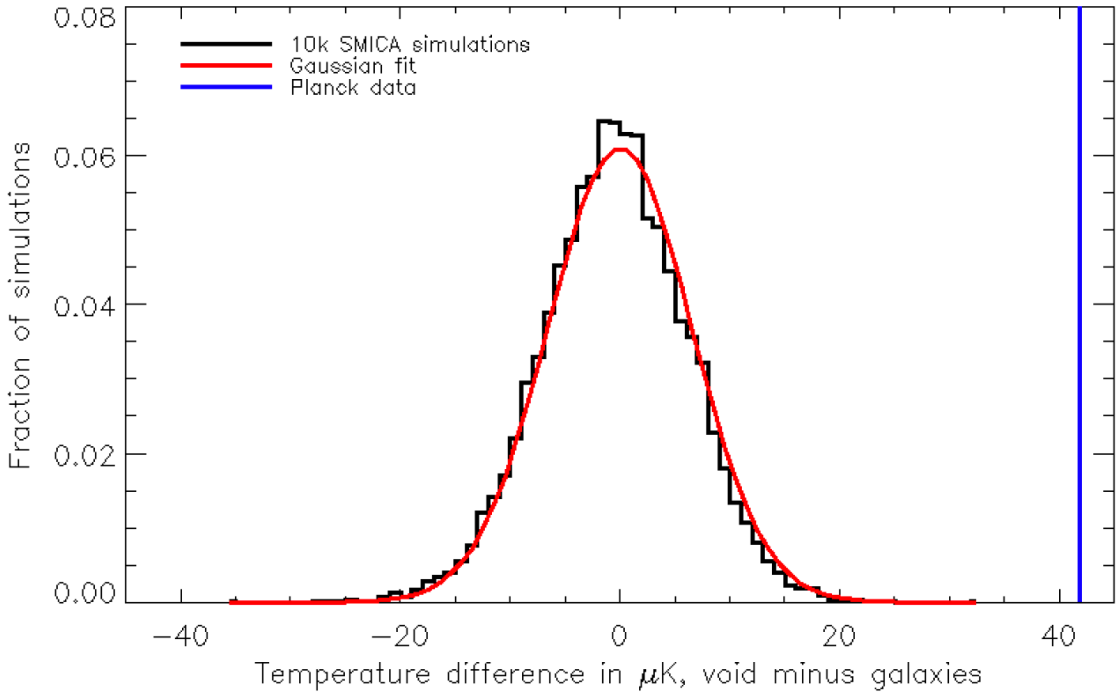
Ultralight axions (ULAs) with masses in the range 10^{-33} eV $\leq m_a \leq 10^{-20}$ eV are motivated by string theory and might contribute to either the dark-matter or dark-energy densities of the Universe. ULAs could suppress the growth of structure on small scales, lead to an altered integrated Sachs-Wolfe effect on cosmic microwave-background (CMB) anisotropies, and change the angular scale of the CMB acoustic peaks. In this work, cosmological observables over the full ULA mass range are computed and then used to search for evidence of ULAs using CMB data from the Wilkinson Microwave Anisotropy Probe (WMAP), *Planck* satellite, Atacama Cosmology Telescope, and South Pole Telescope, as well as galaxy clustering data from the WiggleZ galaxy-redshift survey. In the mass range 10^{-32} eV $\leq m_a \leq 10^{-25.5}$ eV, the axion relic-density Ω_a (relative to the total dark-matter relic density Ω_d) must obey the constraints $\Omega_a/\Omega_d \leq 0.05$ and $\Omega_a h^2 \leq 0.006$ at 95%-confidence. For $m_a \gtrsim 10^{-24}$ eV, ULAs are indistinguishable from standard cold dark matter on the length scales probed, and are thus allowed by these data. For $m_a \lesssim 10^{-32}$ eV, ULAs are allowed to compose a significant fraction of the dark energy.



The hard facts







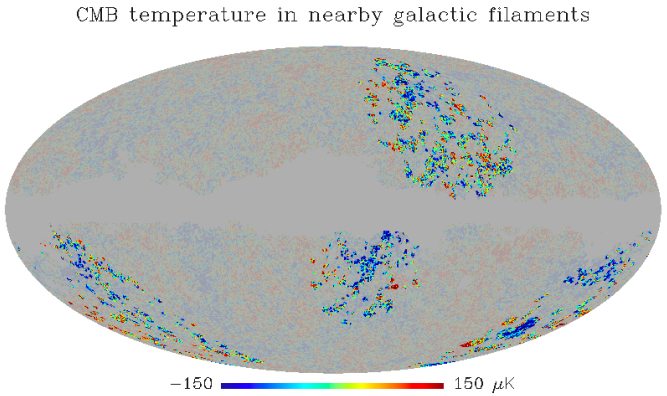
HELP!

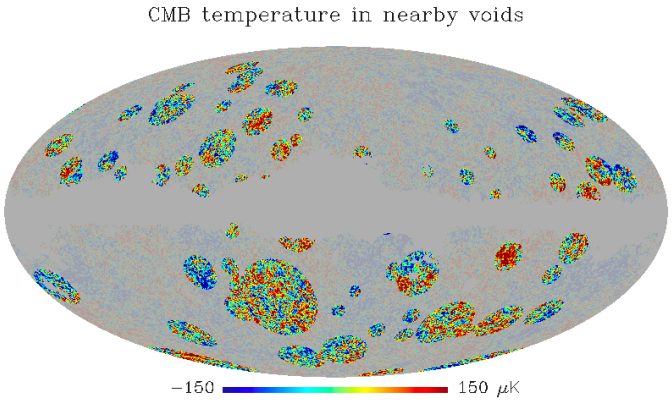
An explanation is needed…

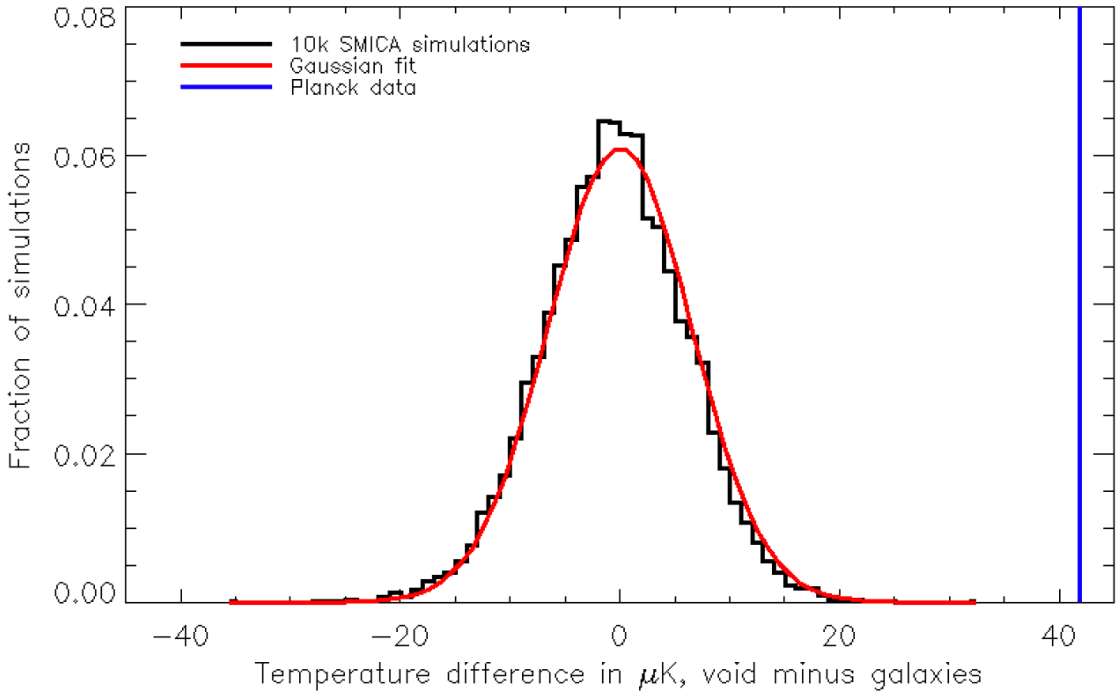
Maybe this has en explanation within ΛCDM
But then either

- We've been overlooking some physical effect
- We've severely miscalculated some known effect

The hard facts







HELP!

An explanation is needed…