# The cosmic shallows: Interactions of CMB photons in extended galaxy halos

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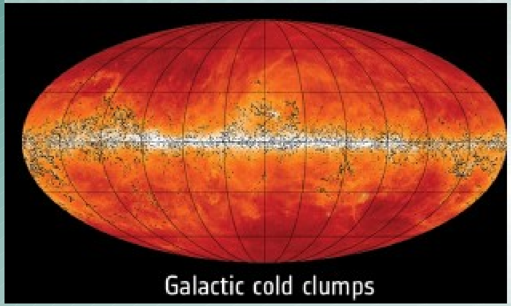
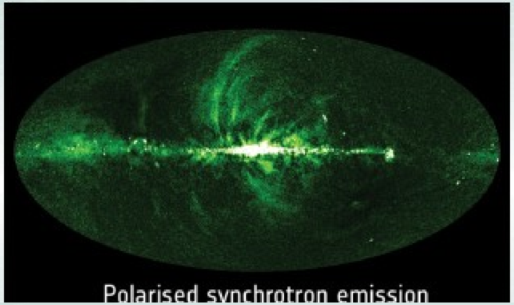
# CMB Foregrounds

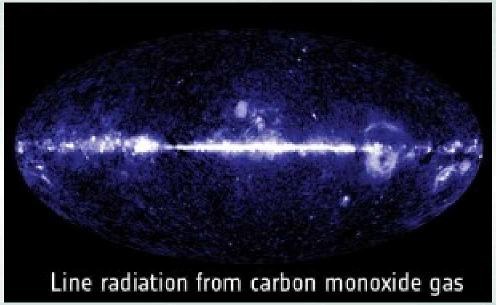
***Interactions affecting the path / energy of the photons between the surface of last scattering and the detectors.***

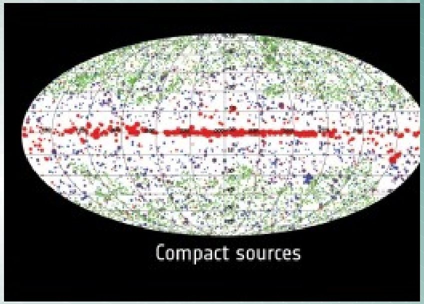
***Interfere with a direct cosmological interpretation of CMB data.***

# 1. INTRODUCTION




* <u>diffuse components in our galaxy</u>: thermal dust emission, line radiation from carbon monoxide gas, diffuse synchrotron emission, and free-free emission

* <u>point-like or compact sources of emission:</u> from pre-stellar cores to galaxy clusters.

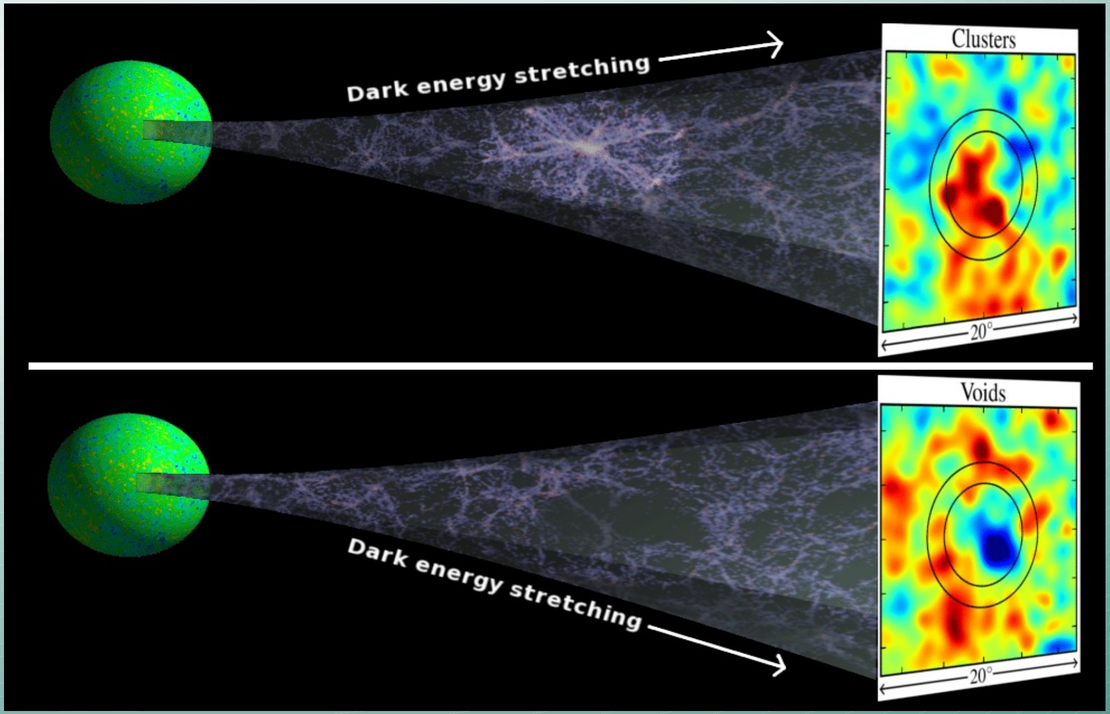
**Integrated Sachs-Wolfe effect** ** (foreground/secondary anisotropy)*

* produced by gravitational potentials

* gain or lose of energy depending on over/underdensities

* best detection at z~0.3

* not removed from CMB data



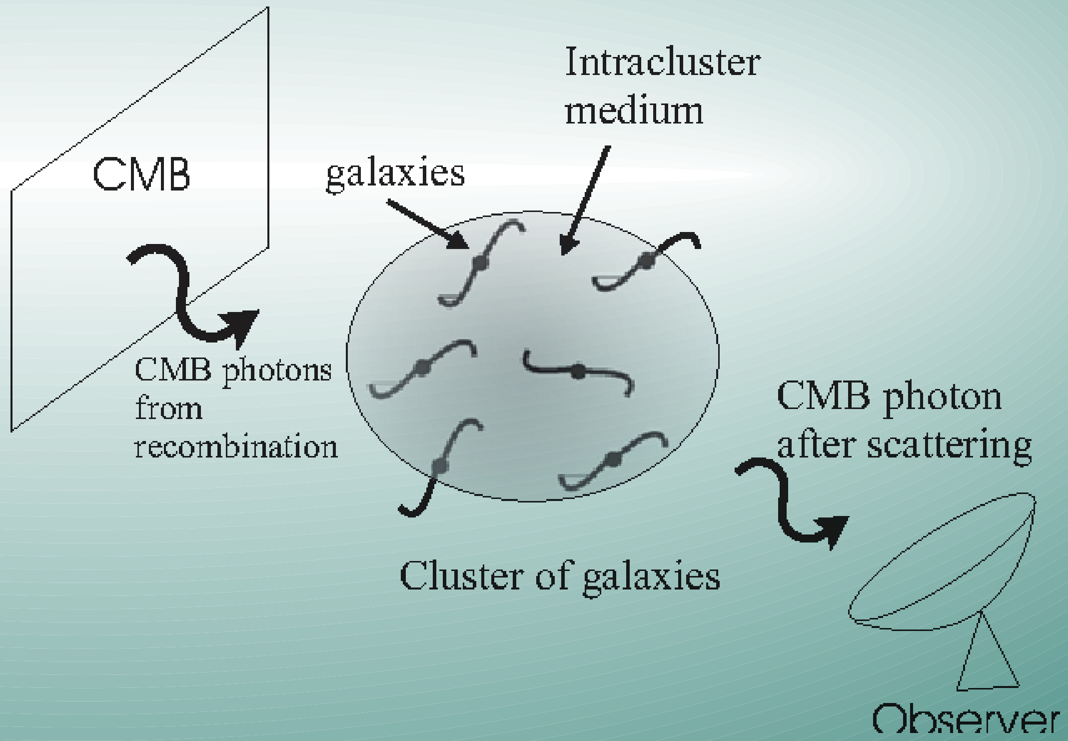
**Thermal Sunyaev-Zeldovich effect** ** (foreground/secondary anisotropy)*

* spectral distortion of the CMB through inverse Compton scattering by high-energy electrons

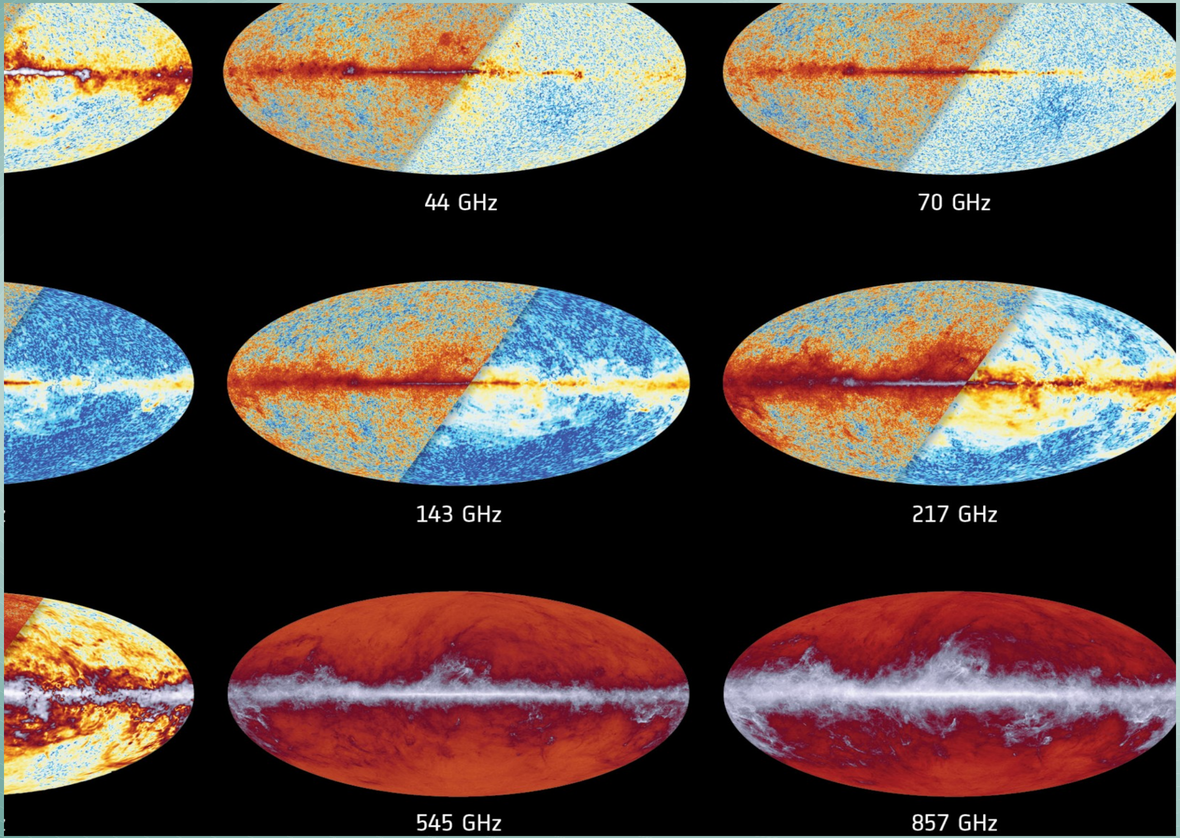
* associated to massive clusters of galaxies

* independent of redshift

* can be extracted from the CMB data



Nine Planck frequency bands




**SMICA *(Spectral Matching Independent Component Analysis)***

* non-parametric method

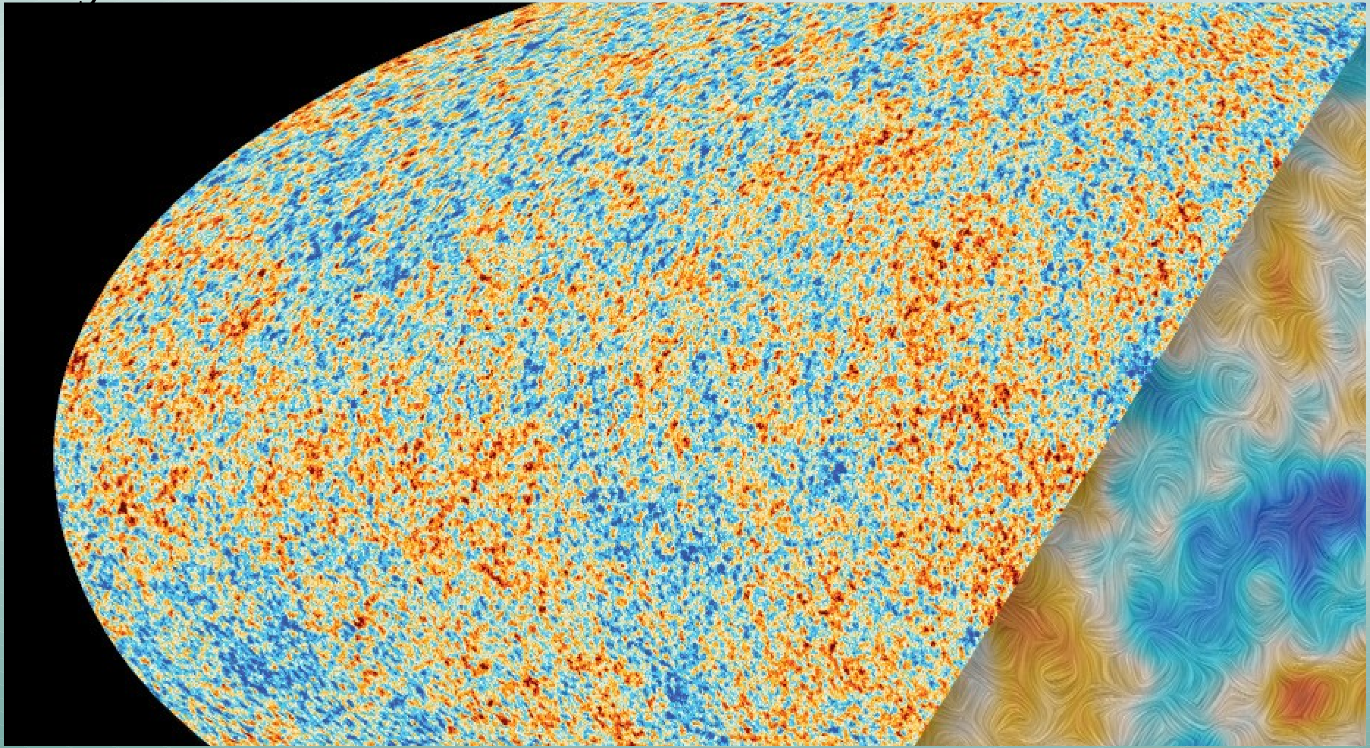
* works in the spherical harmonic domain

* foregrounds are modelled as templates

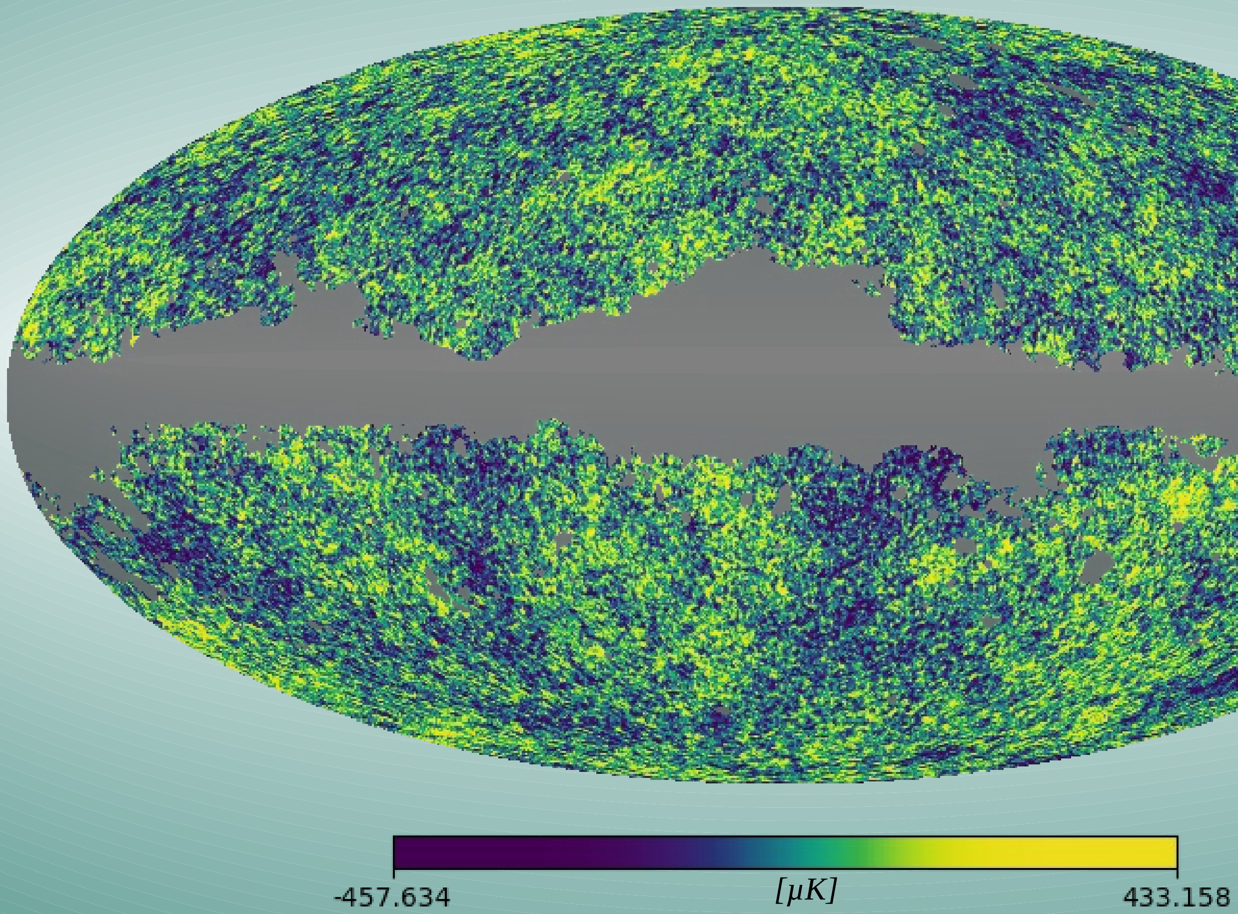
* a set of weights is derived to combine the frequency maps in the spherical harmonic domain to produce the final CMB map

* is the method that performed best on the simulated temperature data

*CMB fluctuations can put strong constraints on cosmological parameters if CMB foregrounds are properly considered.*



**CMB SMICA Intensity map + Common mask** *(Planck Collaboration 2020)* **-** *Nside=2048*



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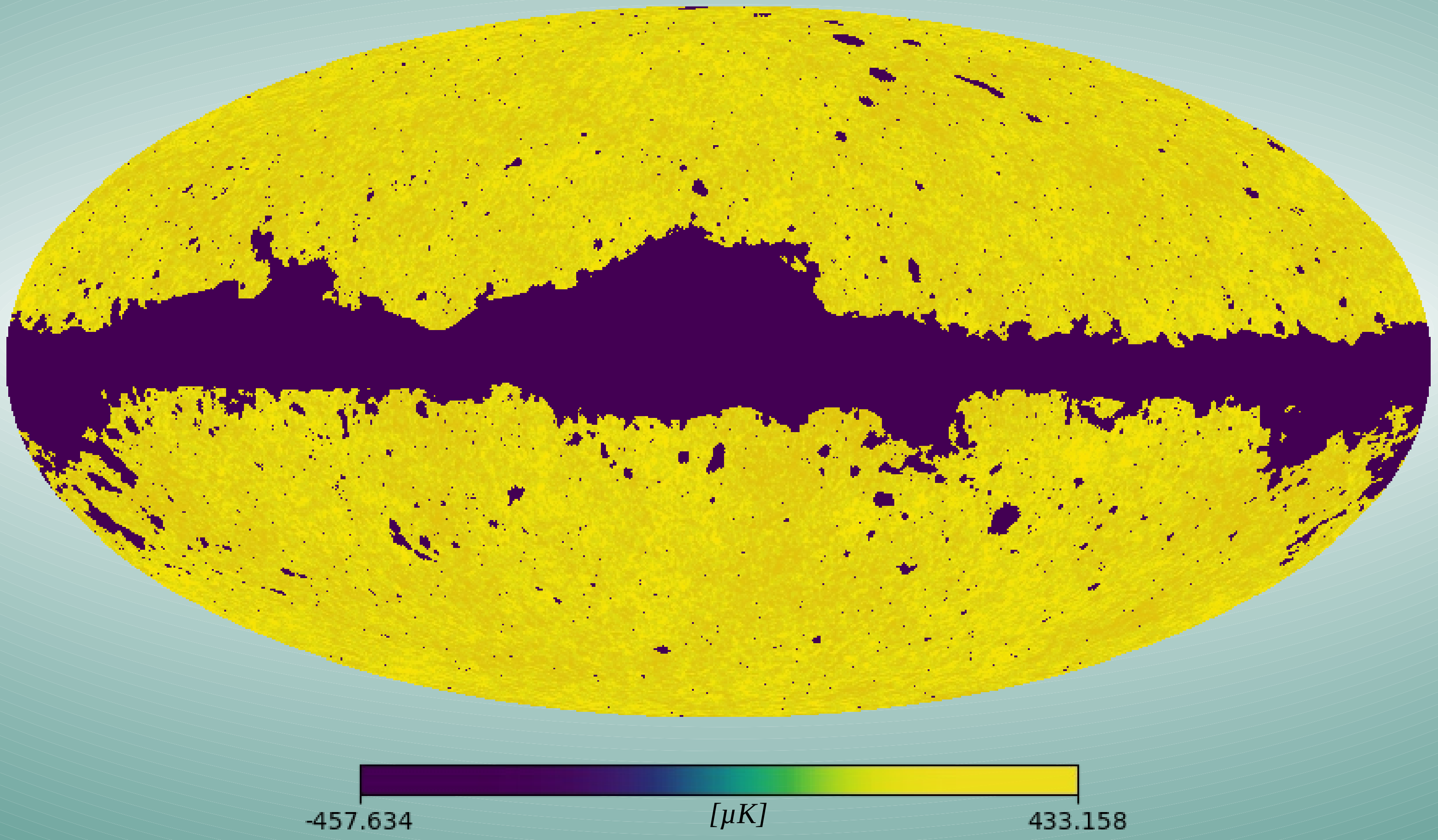


**2MASS galaxy redshift survey** *(2MRS, Huchra et al. 2012)*

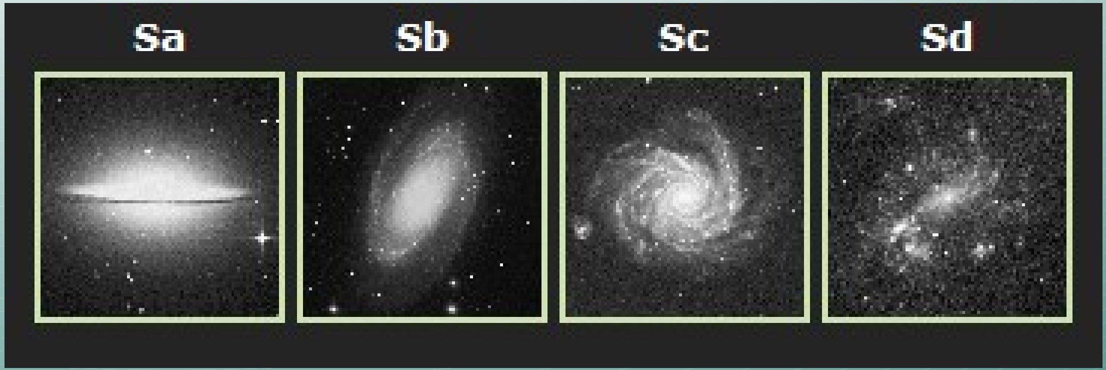
* Galaxy morphology correlates with local environment

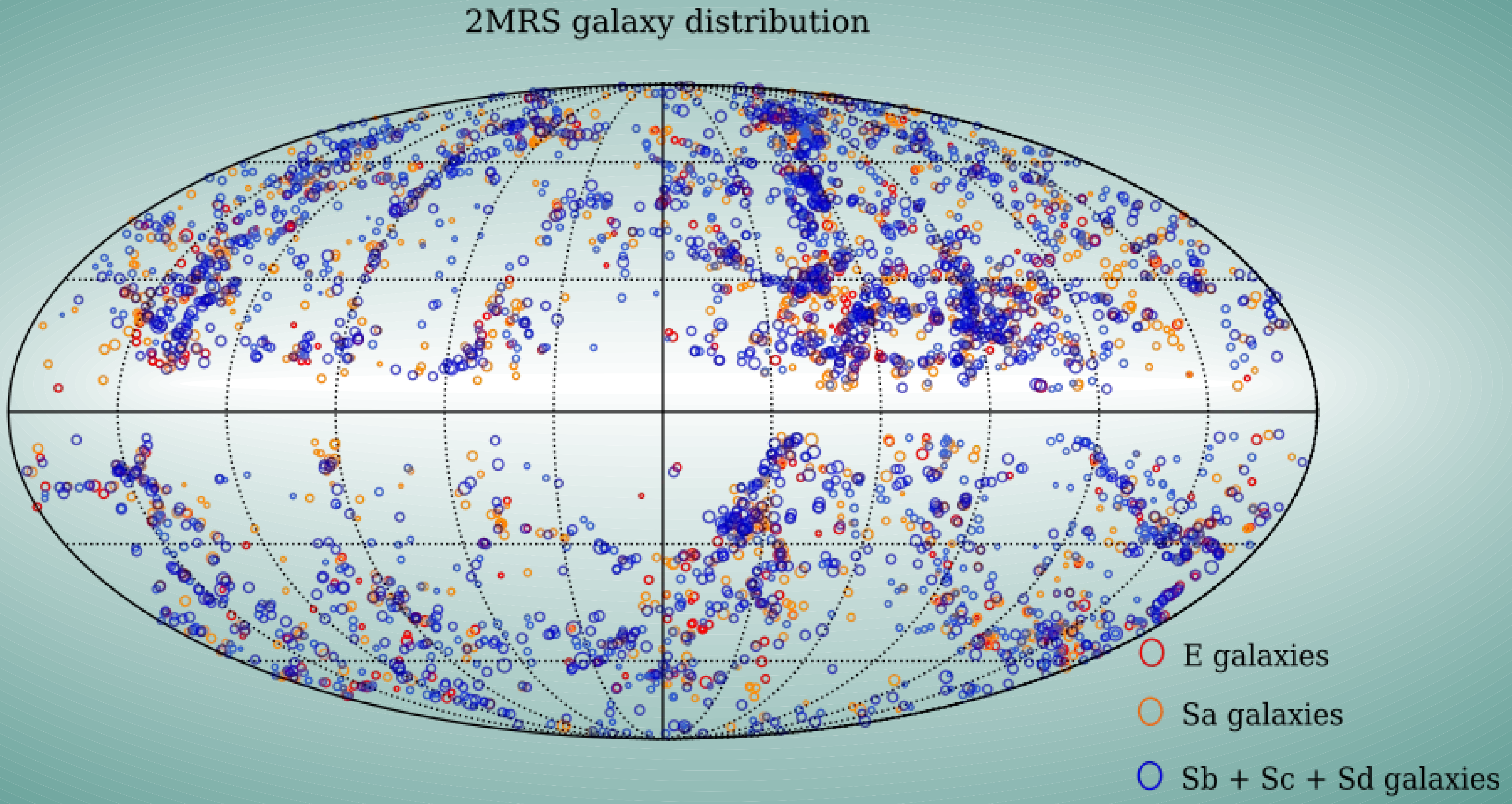
* Due to different merger histories their gaseous surrounding medium could have very different astrophysical properties

<u>Nearby galaxy samples *(0.001<z<0.015)* according to the morphological types:</u>

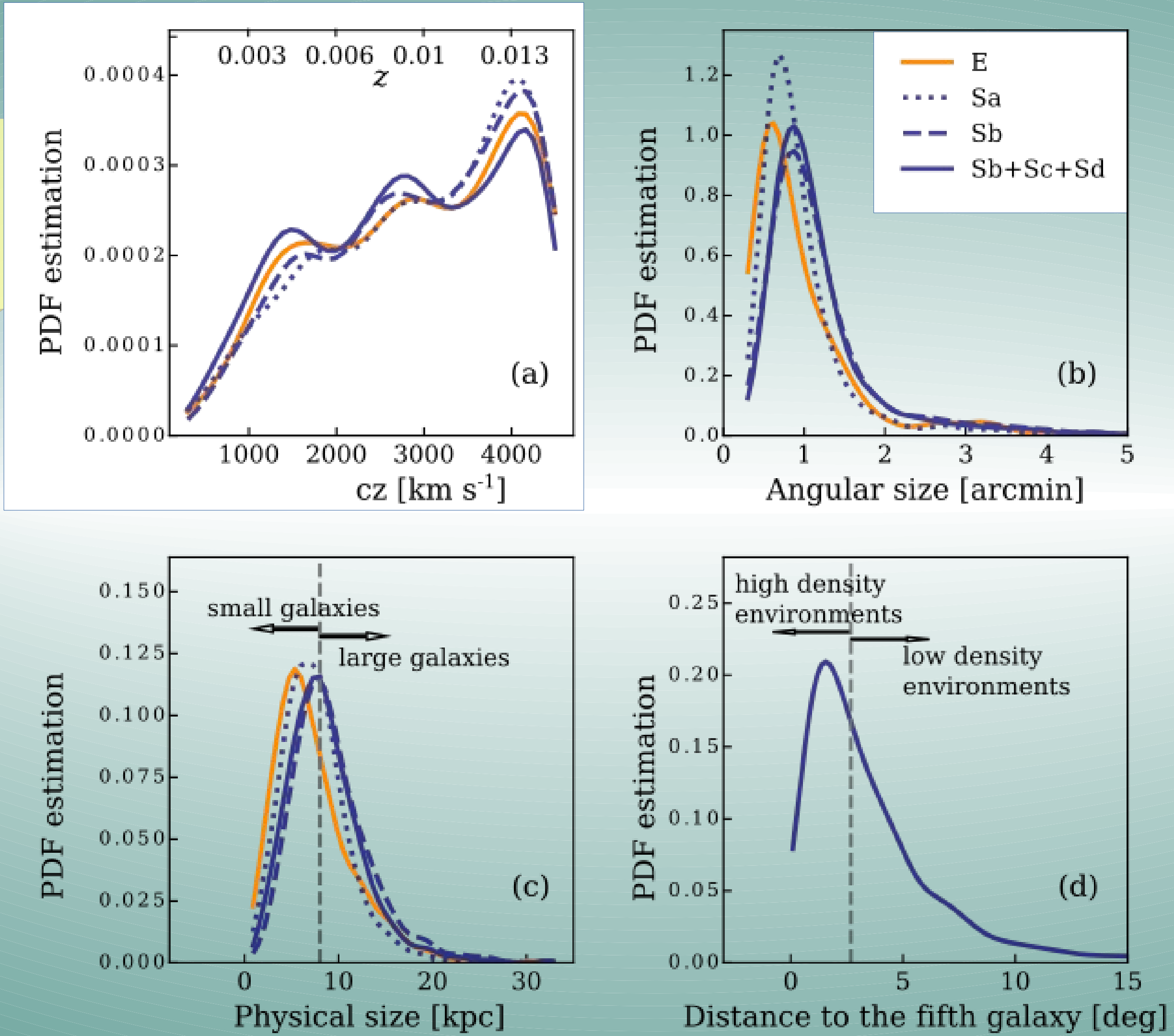
*(Late type spirals)*

| E | S | Sa | Sb | Sb+Sc+Sd |
|---|---|---|---|---|
| 524 | 3589 | 1100 | 1147 | 2489 |




2MRS galaxy distribution
E galaxies
Sa galaxies
Sb + Sc + Sd galaxies

no morphological bias associated to sample depths



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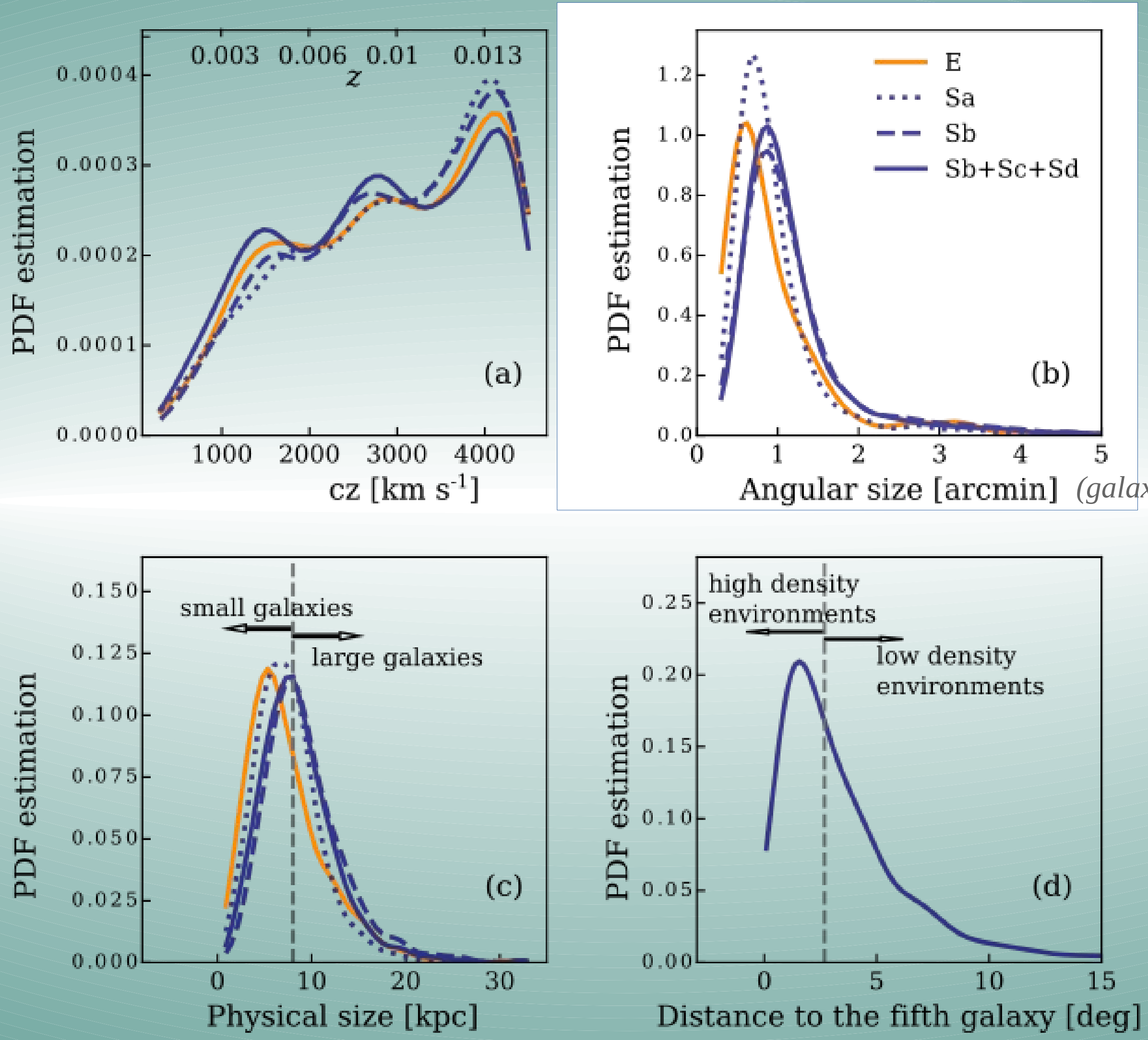
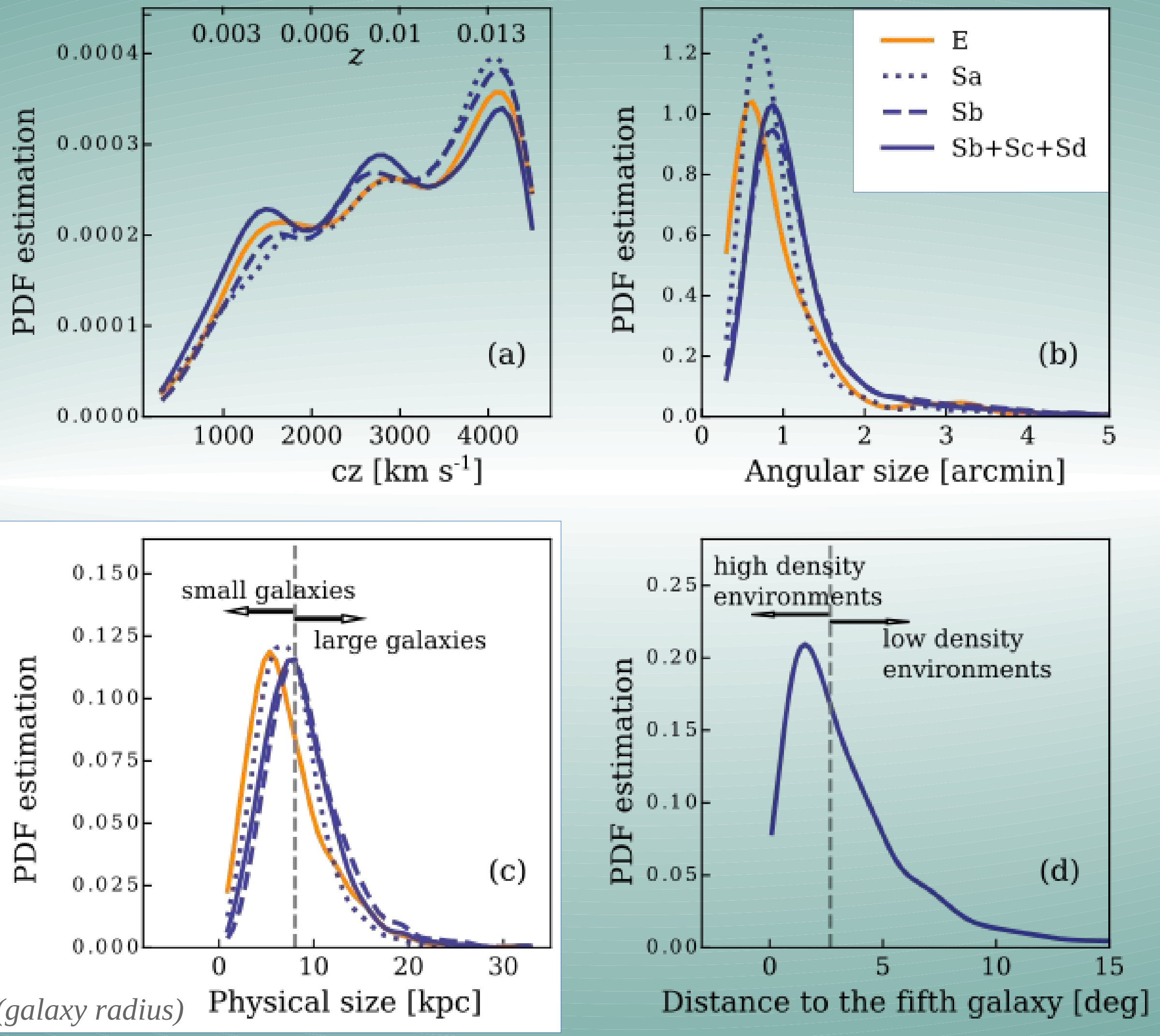


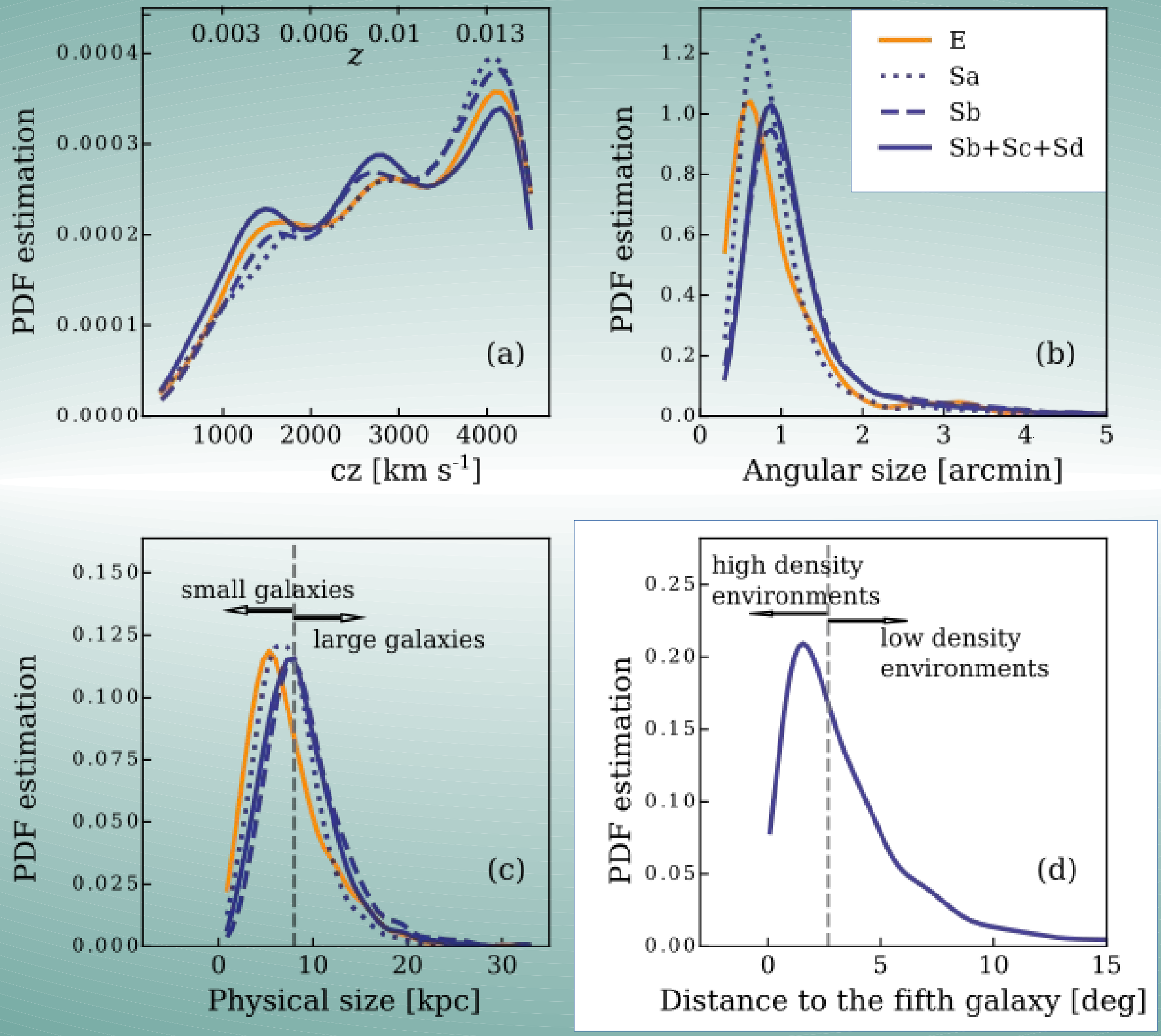

*(galaxy radius)*

*(CMB pixel resolution 1.7 arcmin)*

Spirals and Ellipticals have similar sizes in 2MRS




*(galaxy radius)*




Galaxy size subsamples

Environment in 2MRS.
(redshift-space:
within 500 km/s)

## Calculation of the averaged radial profile for the samples

$$\langle \Delta \mathrm{T} \rangle (\theta) = \frac{1}{N_{\mathrm{gxs}}} \sum_{k=1}^{N_{\mathrm{gxs}}} \left( \frac{1}{N_k} \sum_{i \in C_k} \Delta \mathrm{T}(\mathrm{k}, \mathrm{i}) \right),$$

## Calculation of the average radial profile for the samples

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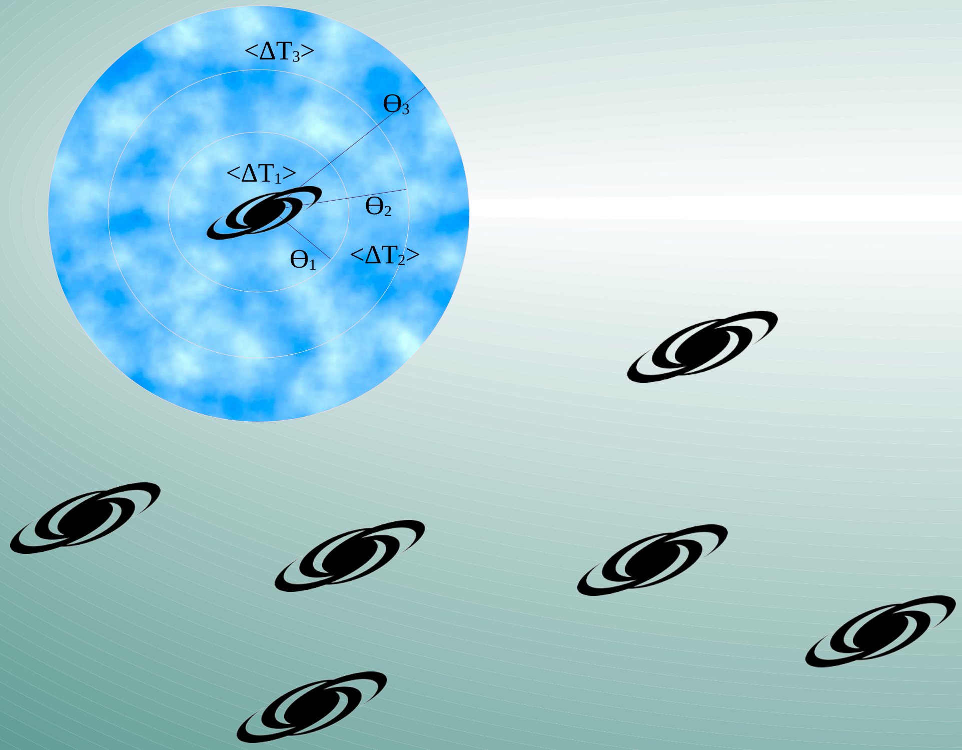


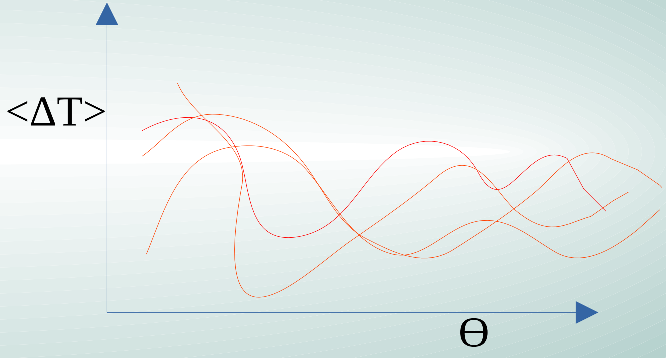

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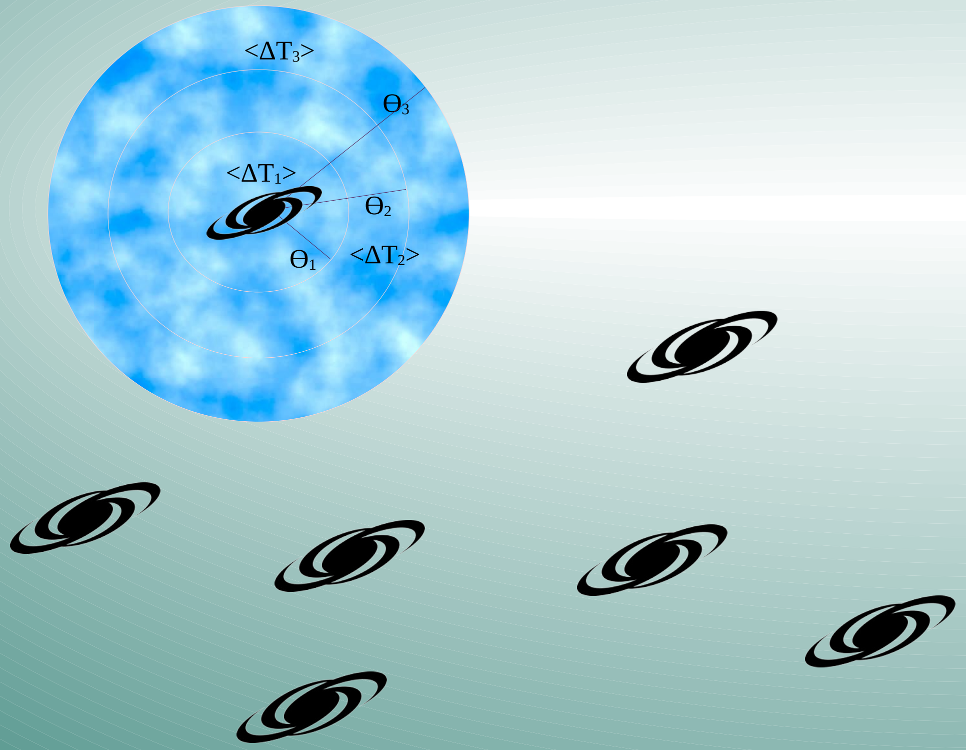


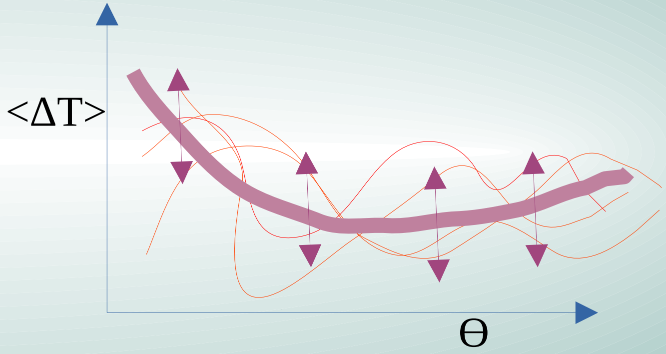

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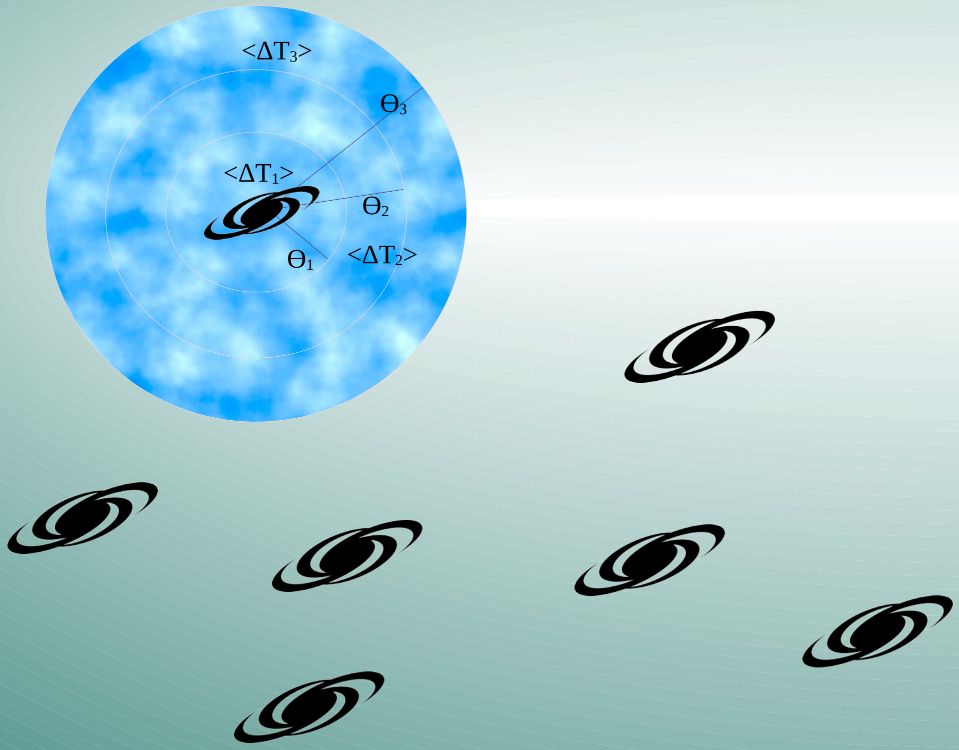
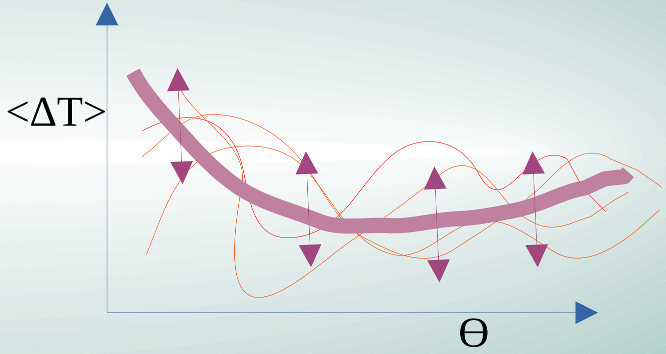
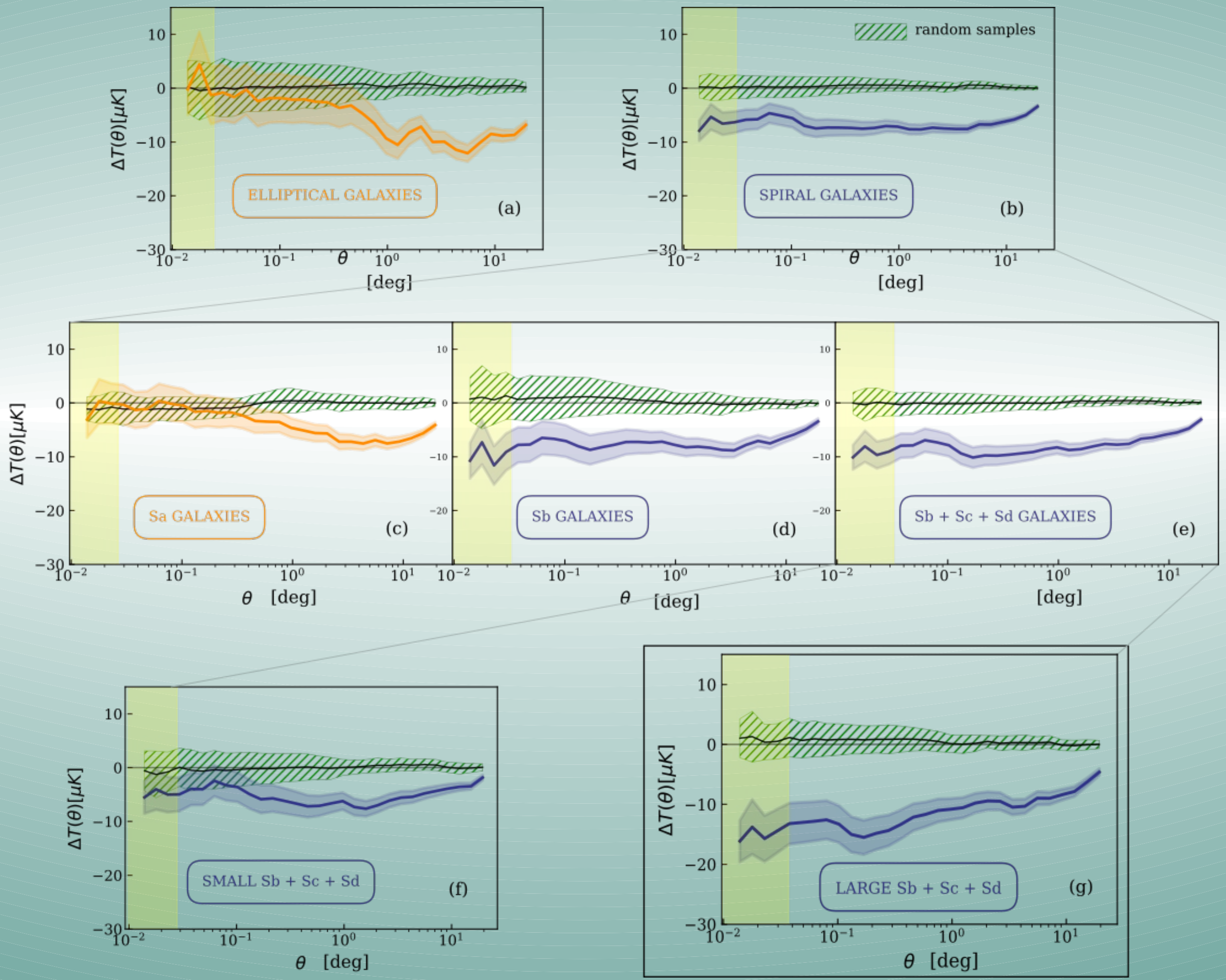



+ 20 random realizations with the same number of objects in the same area to estimate the mean and standard deviation of the control sample

# Temperature profile for the galaxy samples



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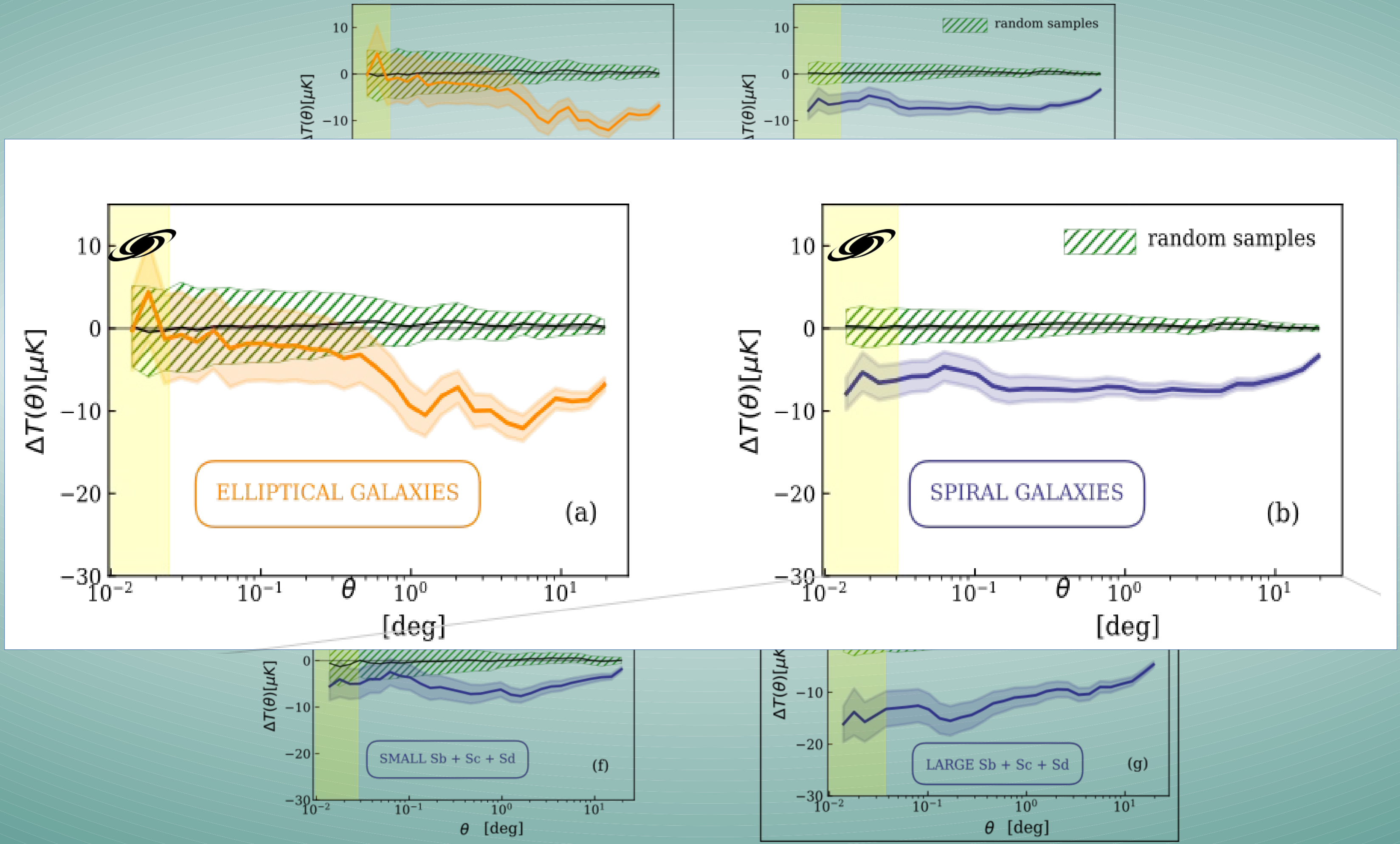
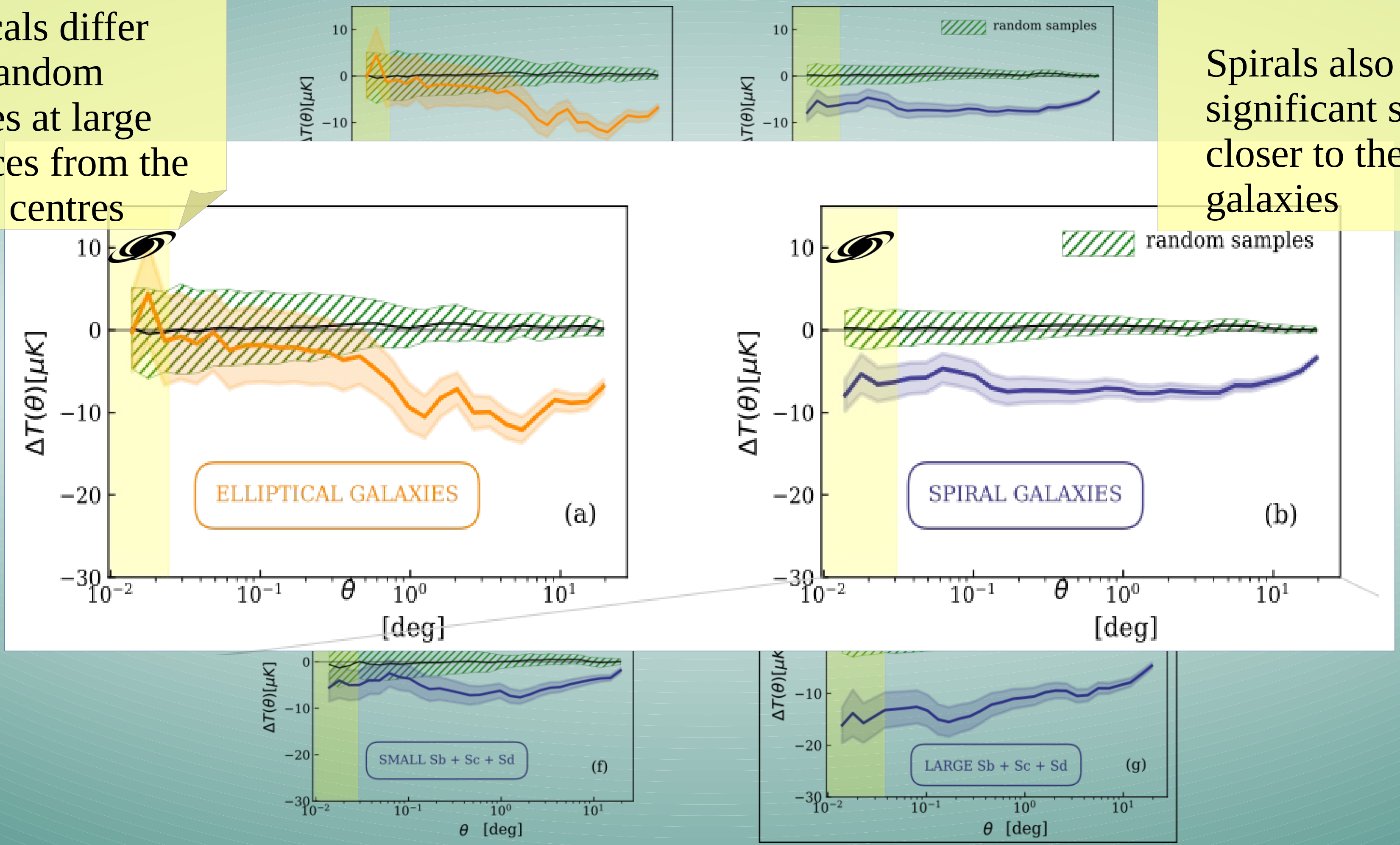


# Temperature profile for the galaxy samples

CMB temperature profile around ellipticals differ from random samples at large distances from the galaxy centres

Spirals also show a significant signal closer to the galaxies



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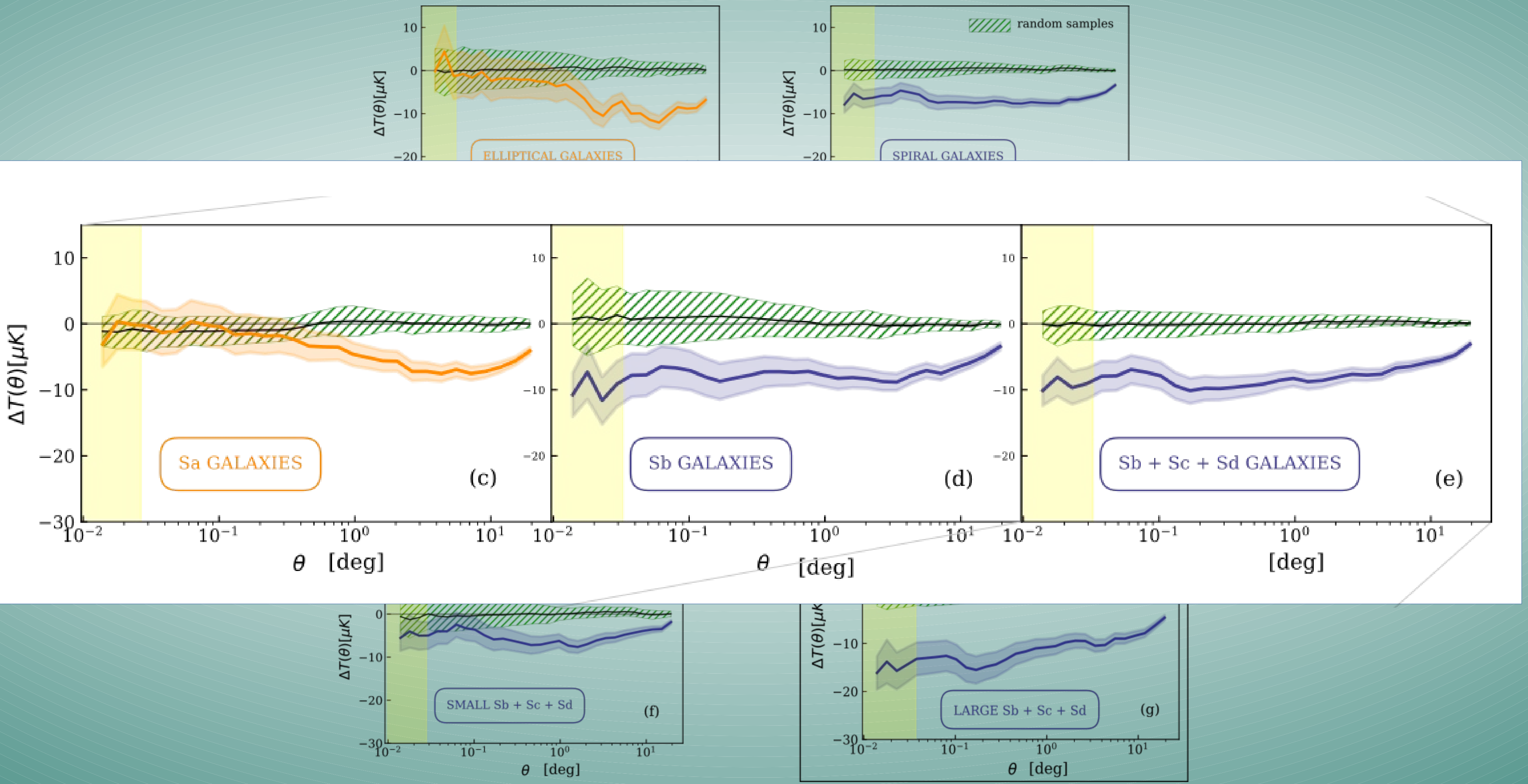

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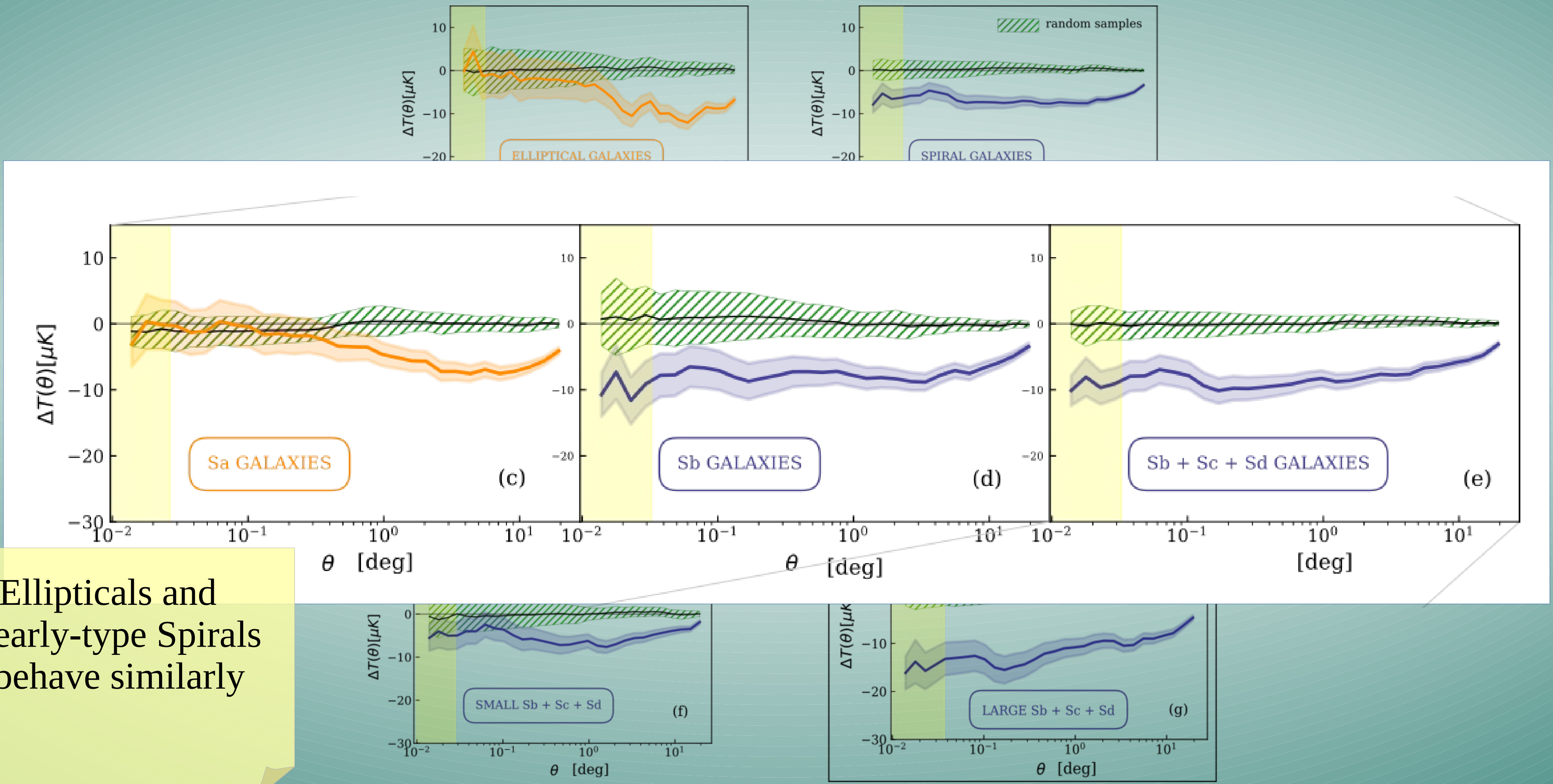
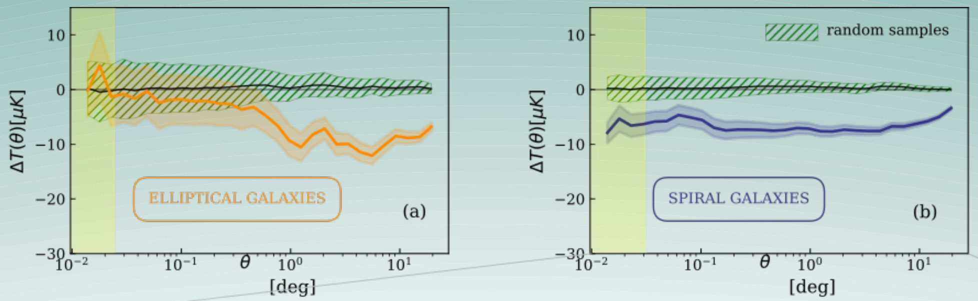
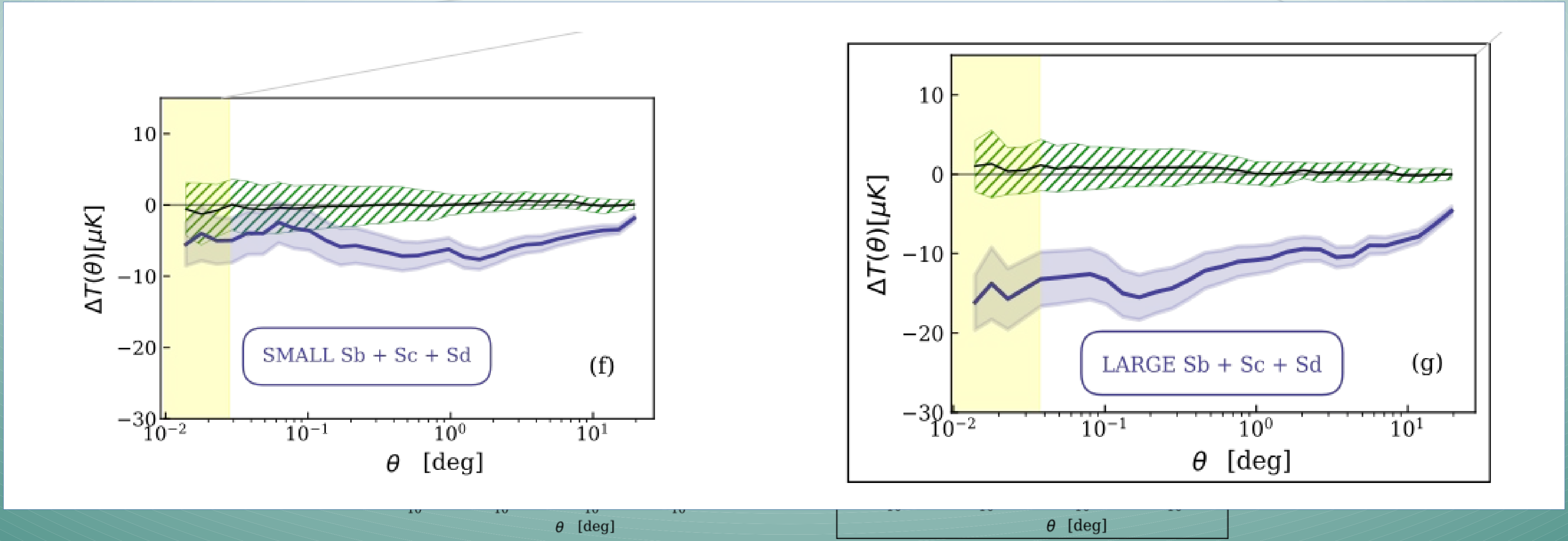



Ellipticals and early-type Spirals behave similarly

# Temperature profile for the galaxy samples



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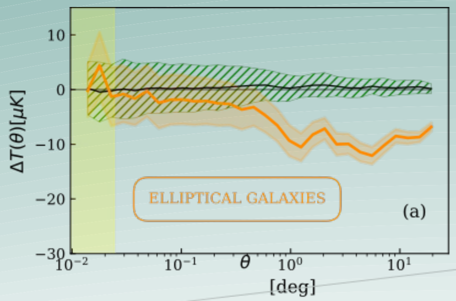
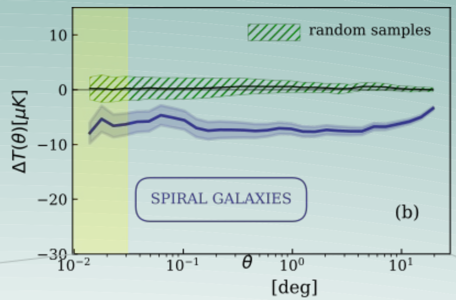
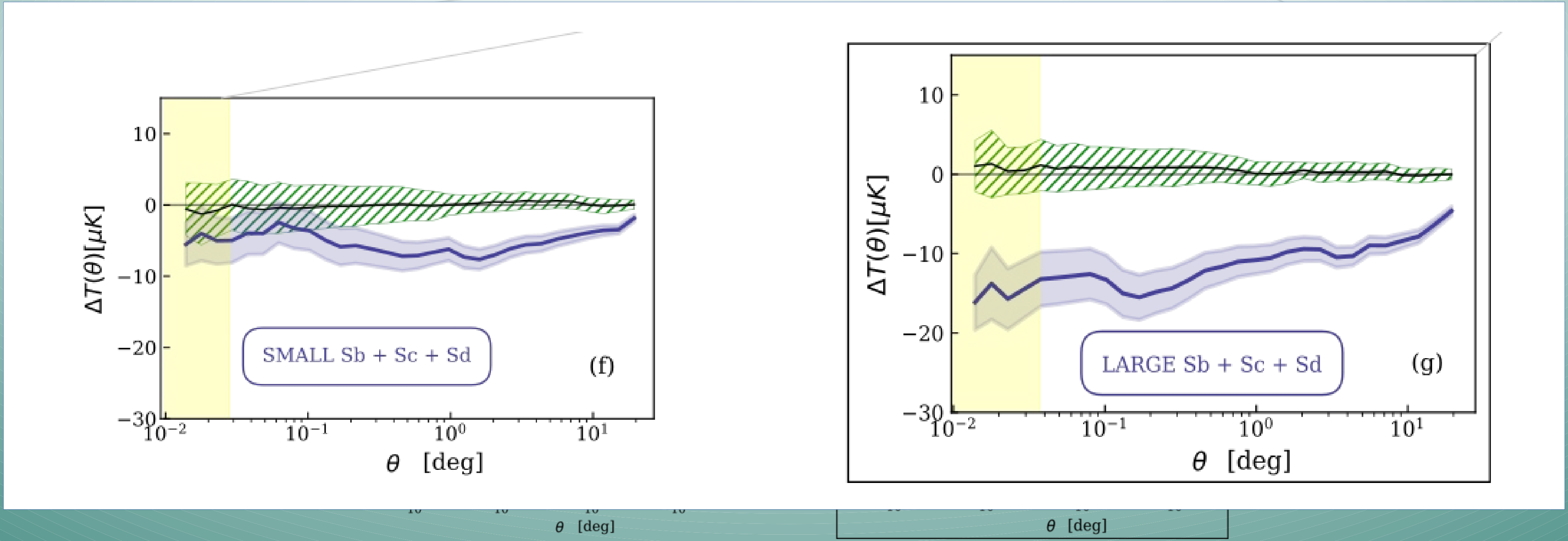
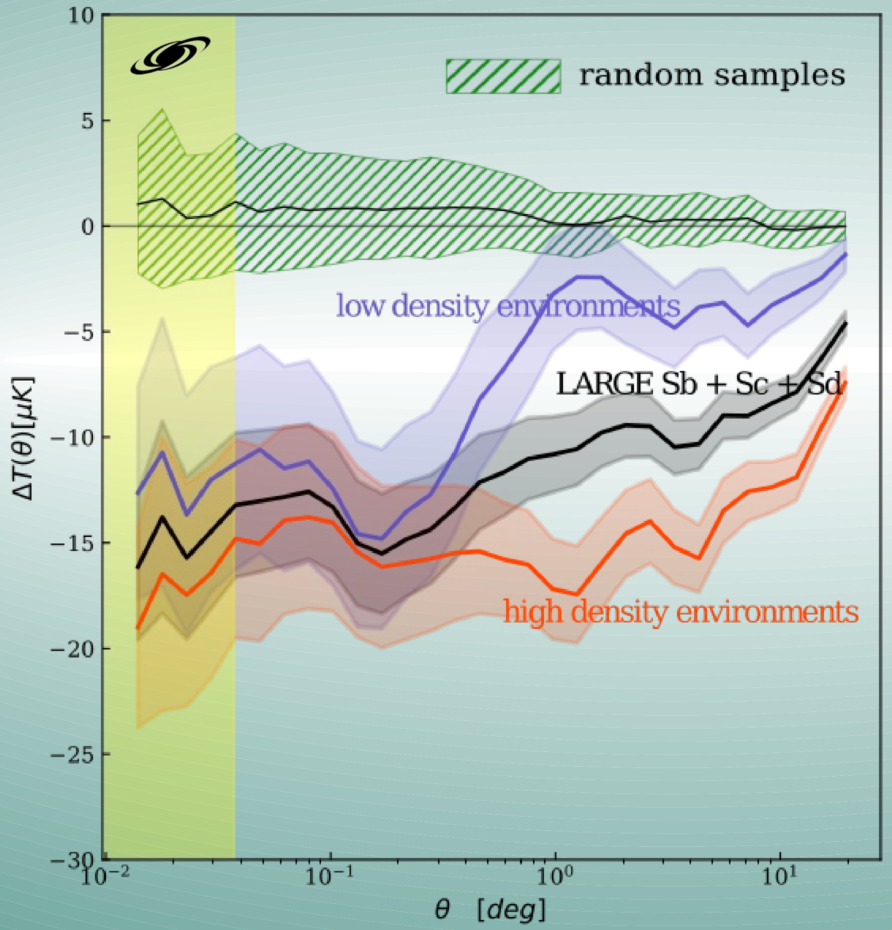



the effect is stronger for large galaxies



# Environment dependence (for large Spiral samples)




At small scales, environment is not relevant.

Due to superposition, the effect at large scales differ significantly

# An attempt of a simple modelling

* statistically significant CMB temperature decrements of ~-15μK around nearby galaxies

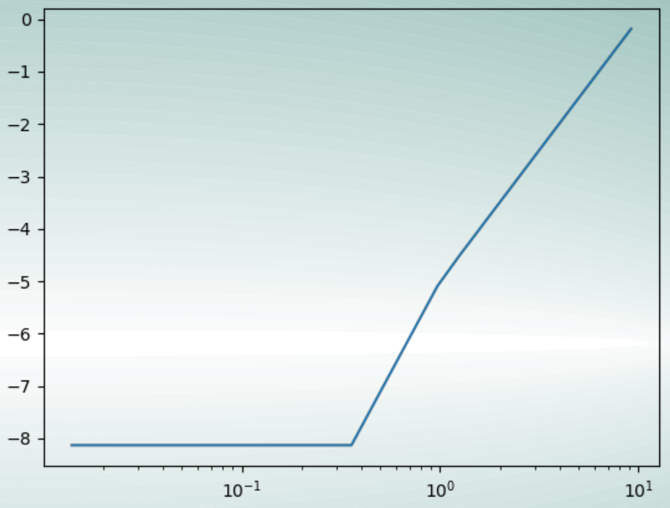
* large effect by large late-type Spirals.

* Due to galaxy clustering, superposition plays an important role.

Systematic large-scale effects of Ellipticals and small Spirals could be induced by large Spirals ?

## Fit of the profile for isolated large Spirals

$$T_A(\theta) = \begin{cases} -8.66 & \text{if } \theta \leq 0.3 \text{ deg} \\ 7\log_{10}(\theta) - 5 & \text{if } 0.3 \text{ deg} < \theta \leq 1 \text{ deg} \\ 5\log_{10}(\theta) - 5 & \text{if } 1 \text{ deg} < \theta \leq 10 \text{ deg} \\ 0 & \text{if } \theta > 10 \text{ deg} \end{cases}$$

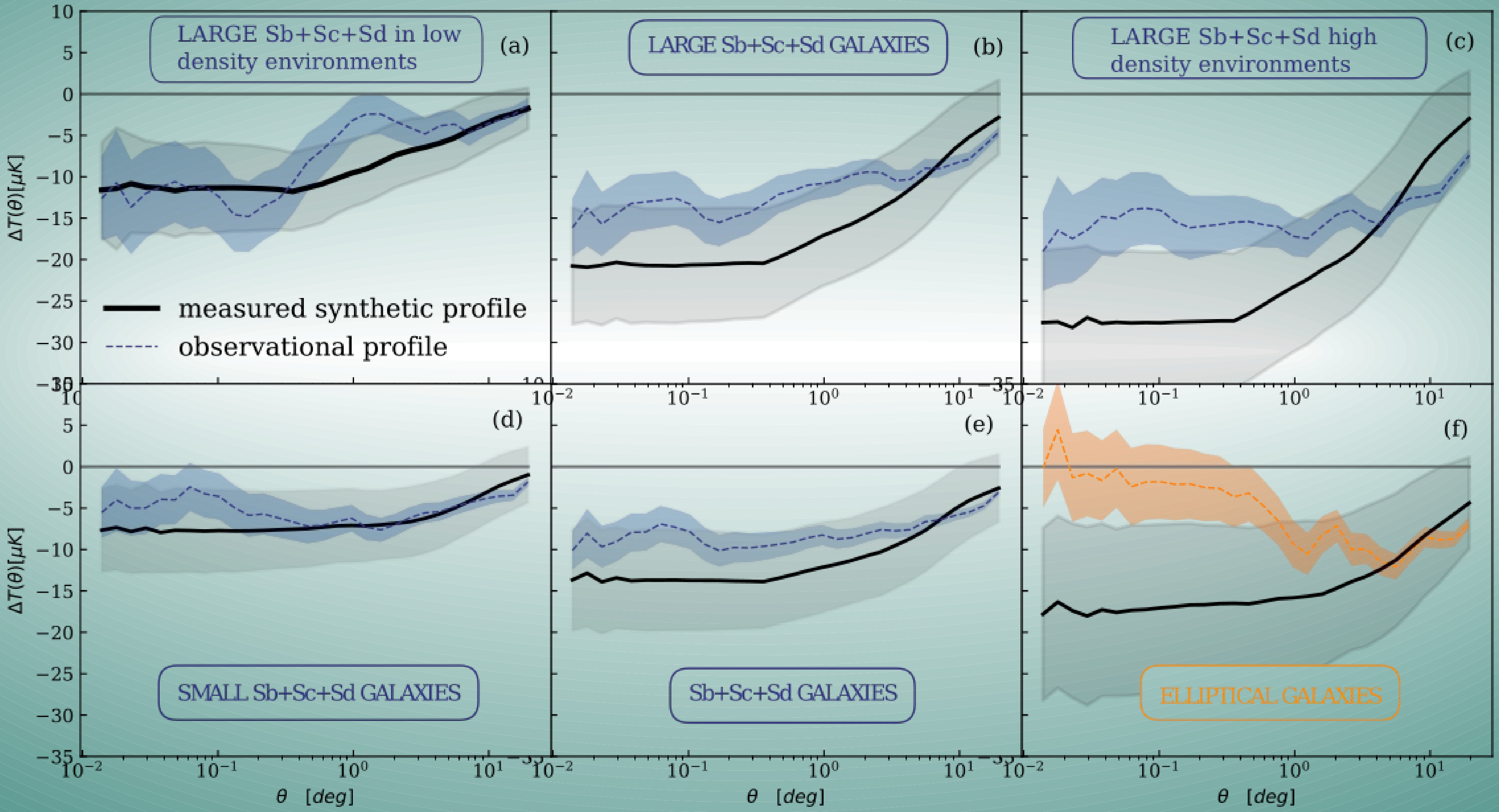



A suite of synthetic CMB maps consistent with the Planck spectrum results are used as background maps

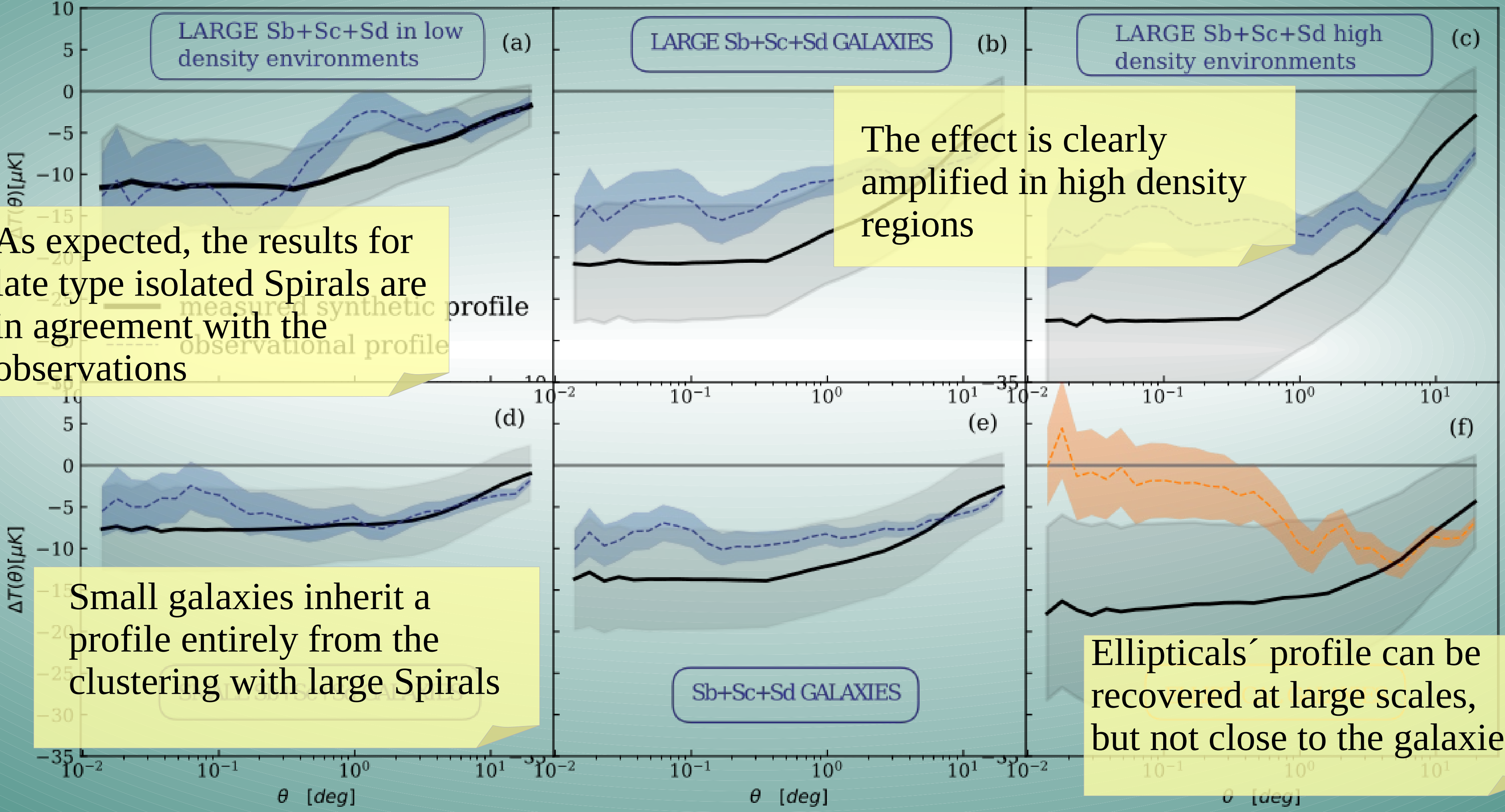
This profile is imposed to the actual positions of large late-type Spirals

Clustering properties of each sample are the same as in the real data

# Simple model of the effects



# Simple model of the effects



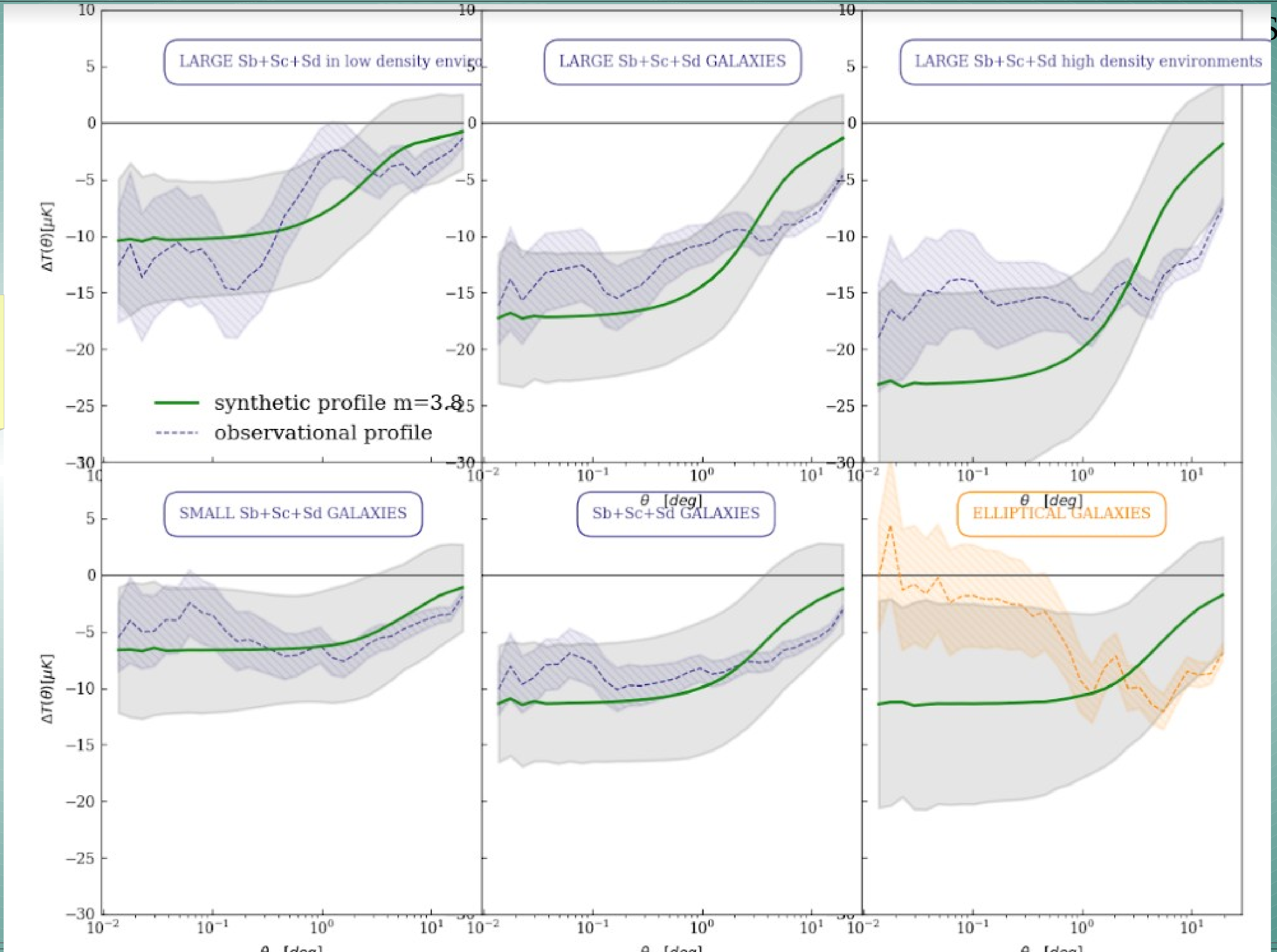

As expected, the results for late type isolated Spirals are in agreement with the observations

The effect is clearly amplified in high density regions

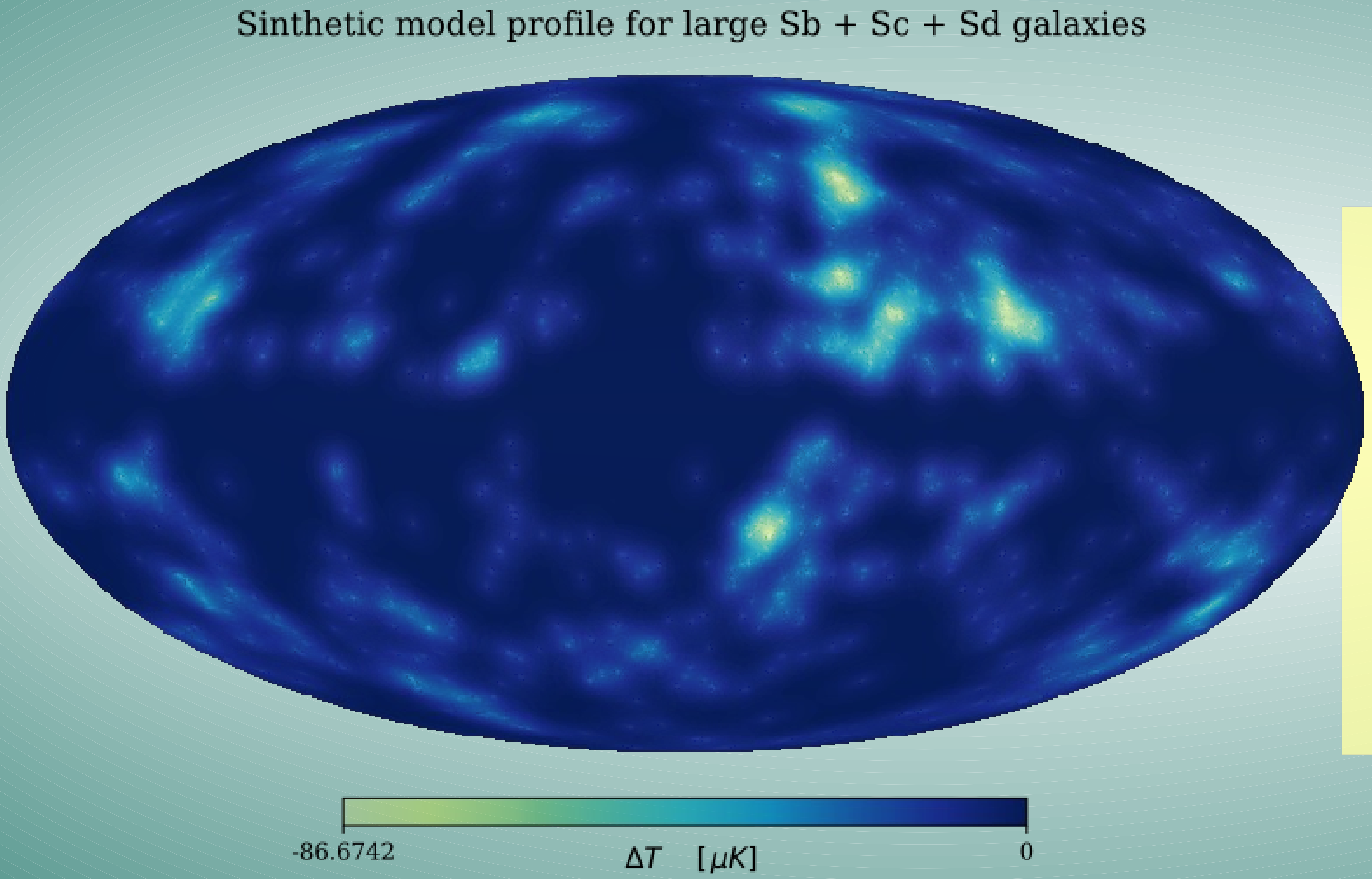
Small galaxies inherit a profile entirely from the clustering with large Spirals

Ellipticals´ profile can be recovered at large scales, but not close to the galaxies

Other model profiles

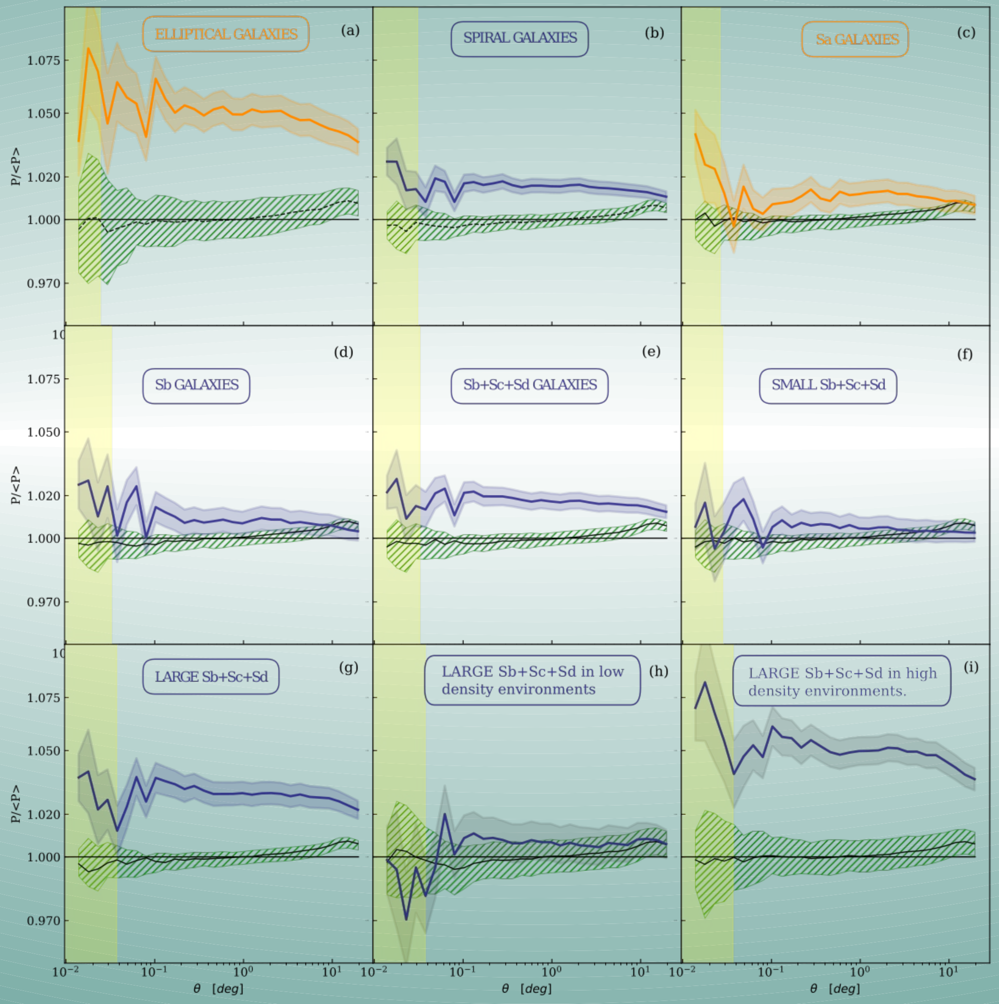


# Simple model




model the effects by its association only to large late-type Spirals gives a reasonable approximation to the observations

# Polarisation flux profile for the galaxy samples



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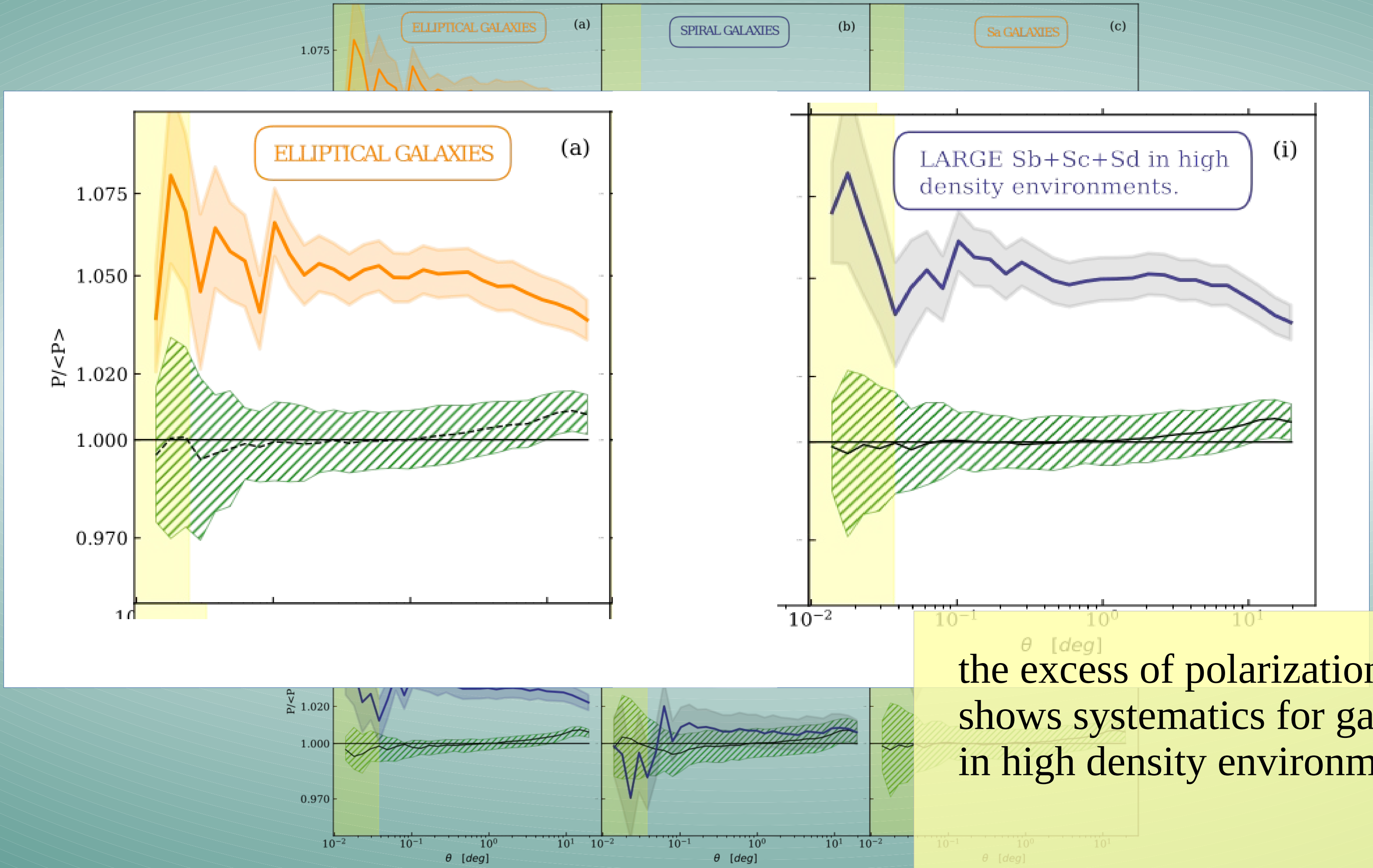
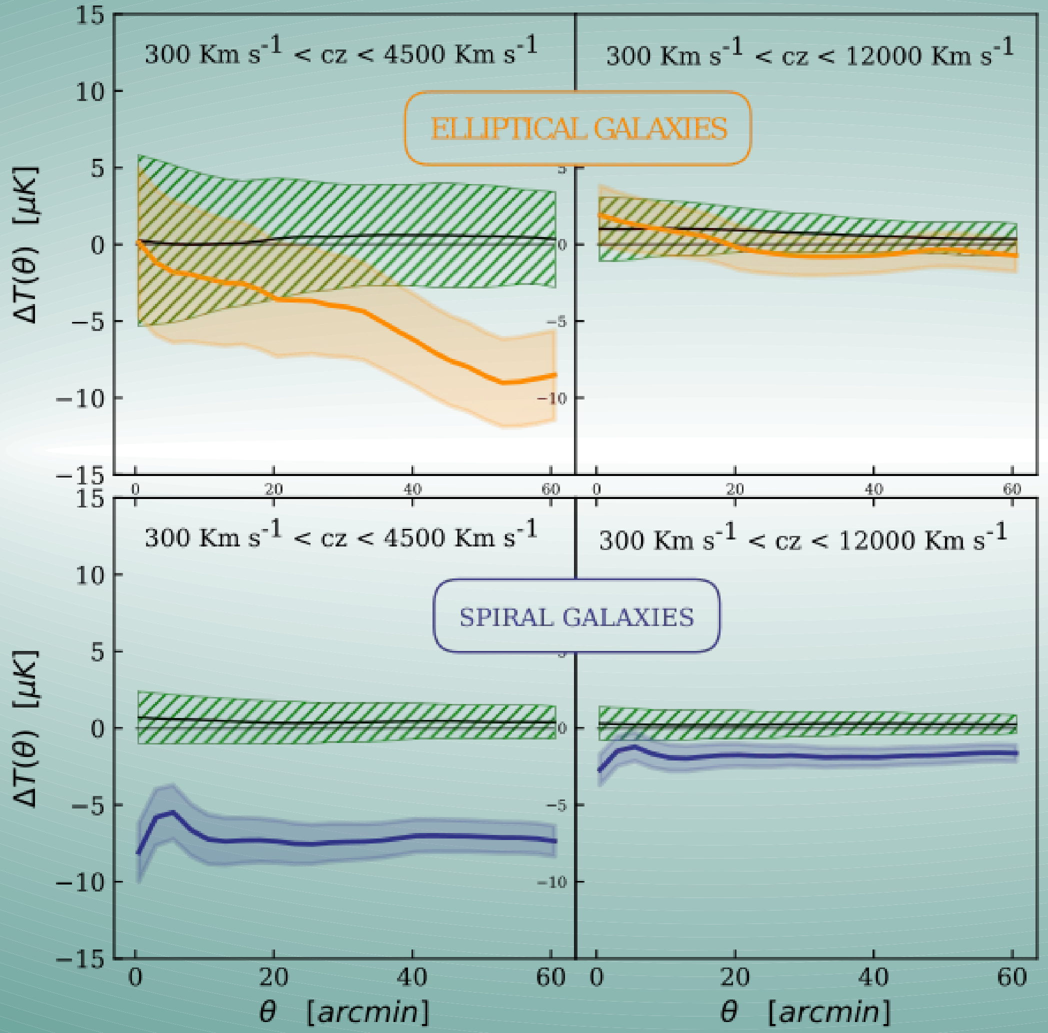


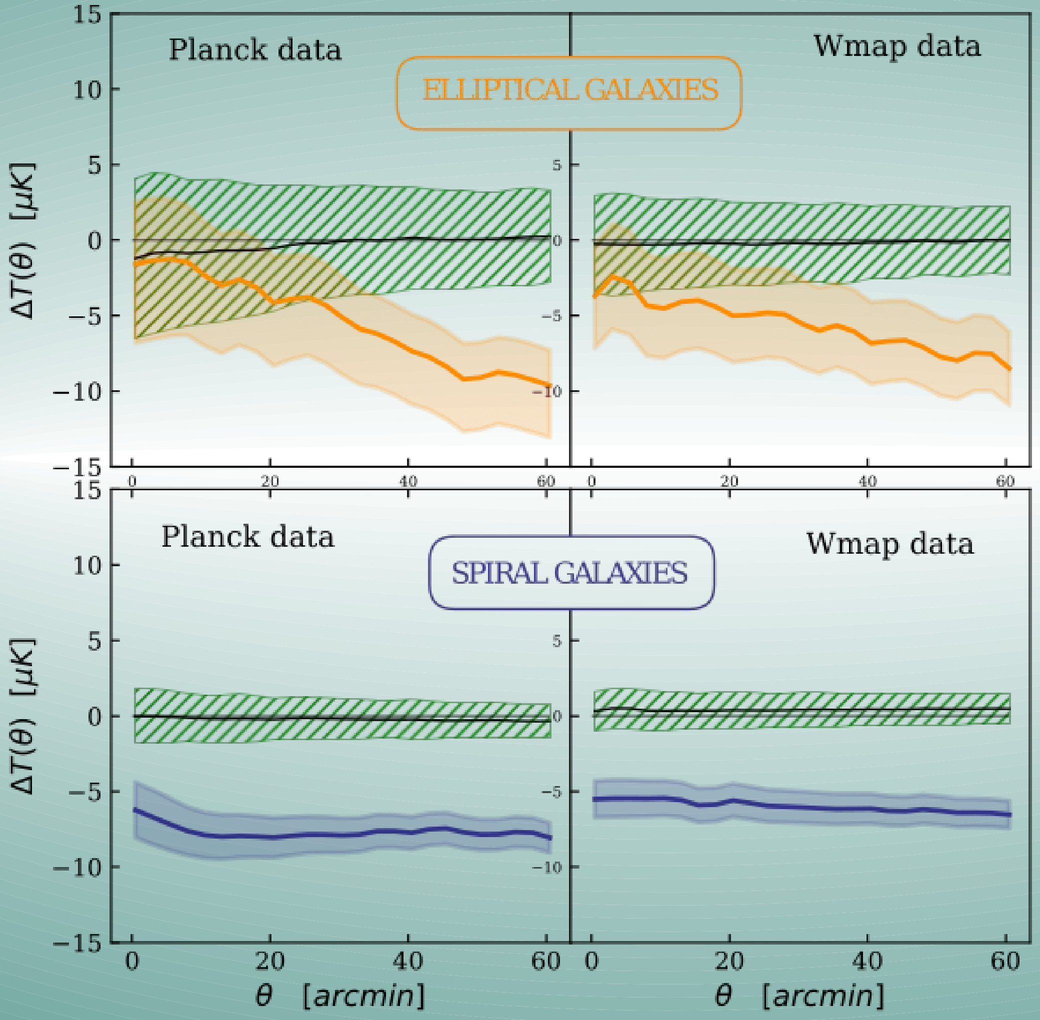

the excess of polarization flux shows systematics for galaxies in high density environments

# Temperature decrement dependence on sample redshift



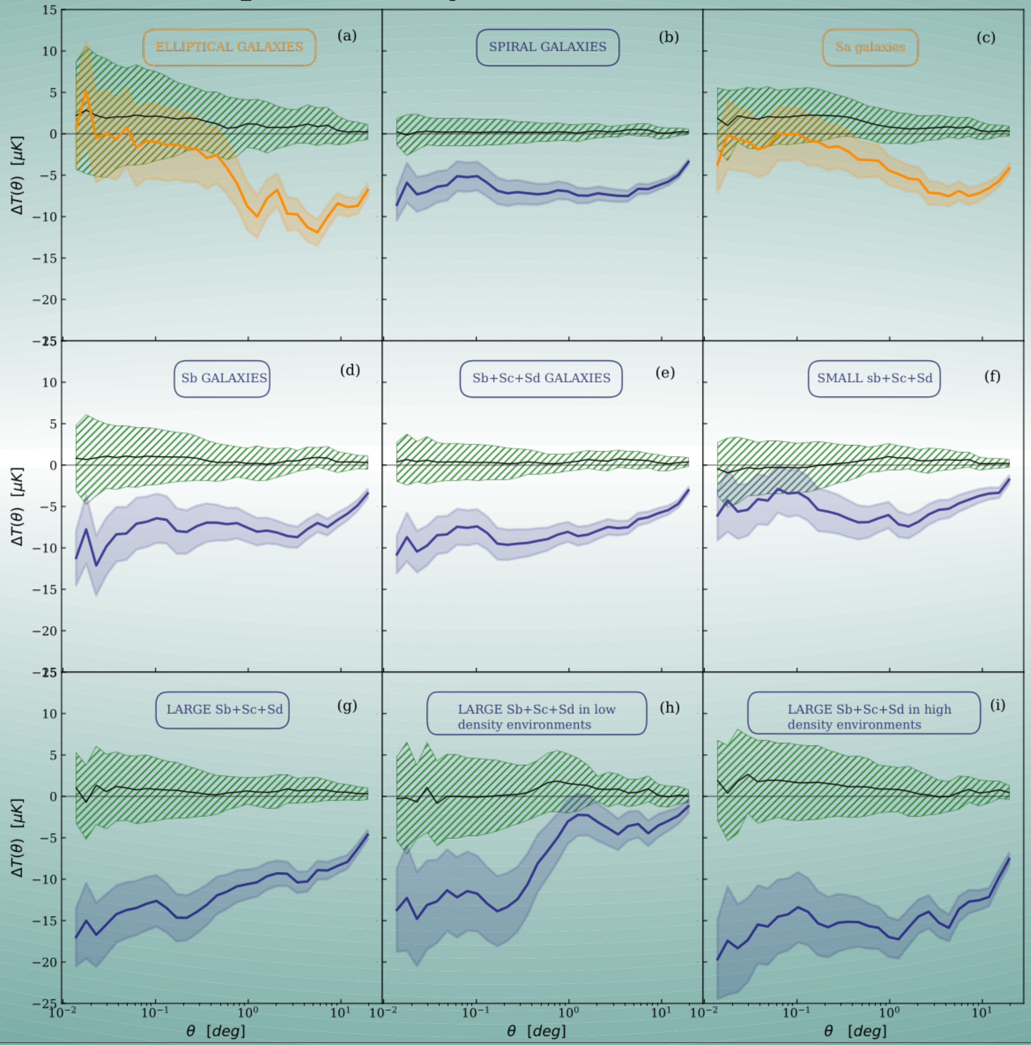

The signal vanishes for the more distant galaxies.
This reinforces the hypothesis that the fluctuating foreground effect is due to the nearby galaxies.

# Confirmation with WMAP data




WMAP and Planck data give consistent results

# Temperature profiles using SMICA map with Sunyaev-Zeldovich sources removed




SZ effect is not likely a significant driver of our results

# SUMMARY

Surrounding regions of nearby galaxies (cz <5000 km/s), particularly large Spirals, have systematic temperature decrements (~-15μK) extending to Mpc scales, ie. 1-2 orders of magnitude the galaxy optical radius.

.

Our results derived from the Planck collaboration temperature maps are also confirmed with the final release of the WMAP sky maps.

# SUMMARY

Results using Planck maps with removed SZ sources have the same behaviour.

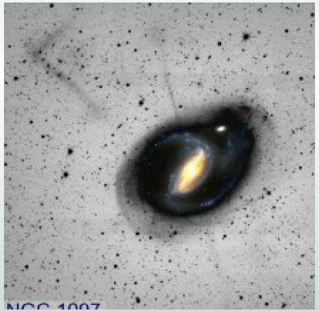
Polarization Flux measures also show systematics associated to galaxies in high density environments.

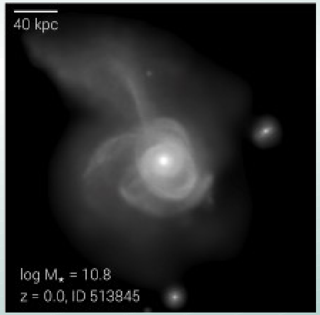
Work in progress also show that in these galaxy neibourhoods, the temperature variance is systematically lower than expected.

# SUMMARY

Accretion of substructure processes onto galaxies may be clue to understand the underlying physics of the observed foreground as CMB photon interactions.

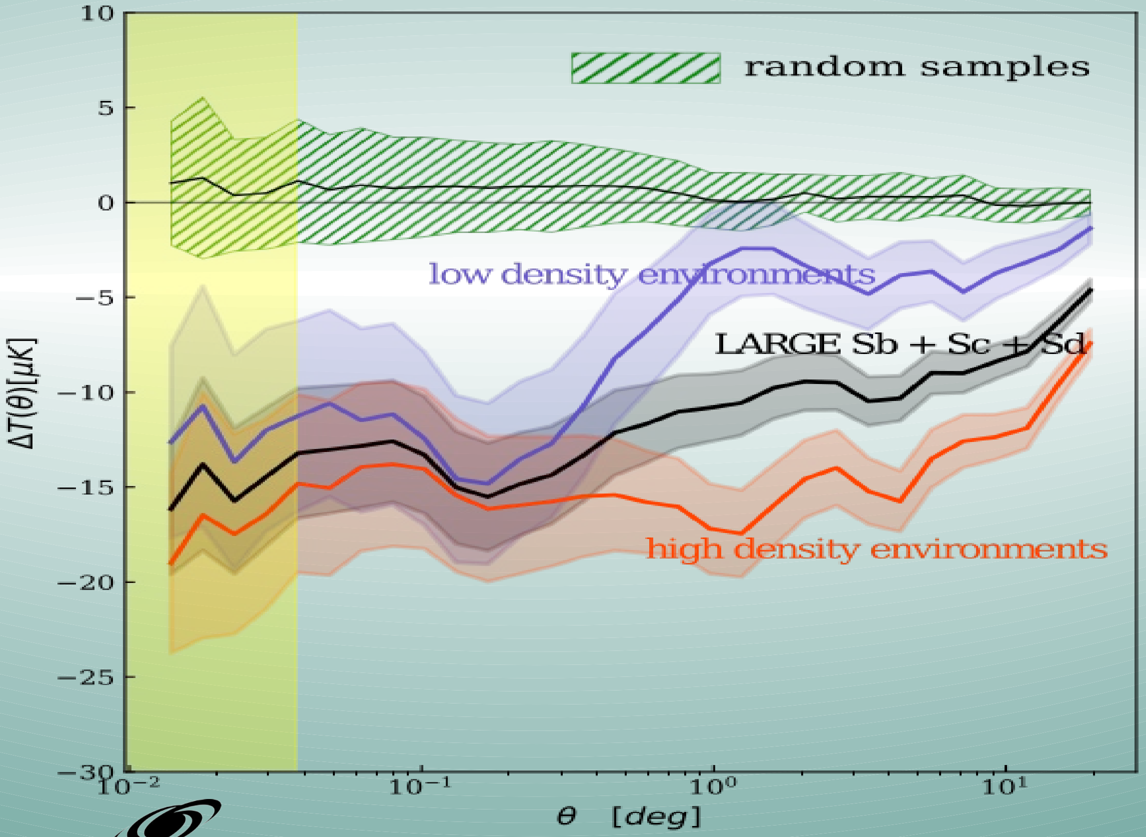
From Martinez Delgado et al. 2021






In a forthcoming paper *(Boero et al., in preparation)* we will address the small, but still detectable, effects on the CMB power spectrum.

# Thank you !


random samples
low density environments
LARGE Sb + Sc + Sd
high density environments
$\Delta T(\theta)[\mu K]$
$\theta$ [deg]
10
5
0
−5
−10
−15
−20
−25
−30
$10^{-2}$
$10^{-1}$
$10^{0}$
$10^{1}$