

# Superstructures and voids: their global dynamics and galaxy properties

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I A T E



# OUTLINE



## I. The cosmic web

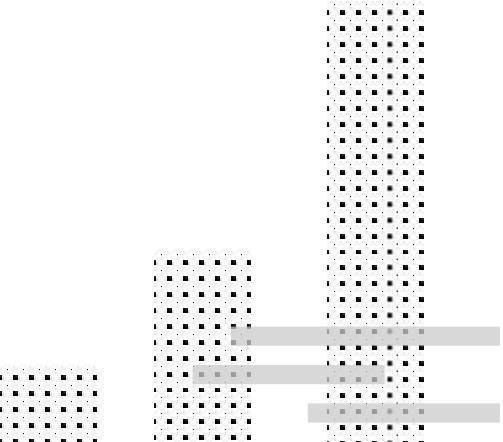
- Large Scale Structure (LSS)
- Identification of superstructures and voids

## II. LSS dynamic and environmental effects

- LSS flows
- LSS as galaxy global environment

## III. The low surface brightness universe

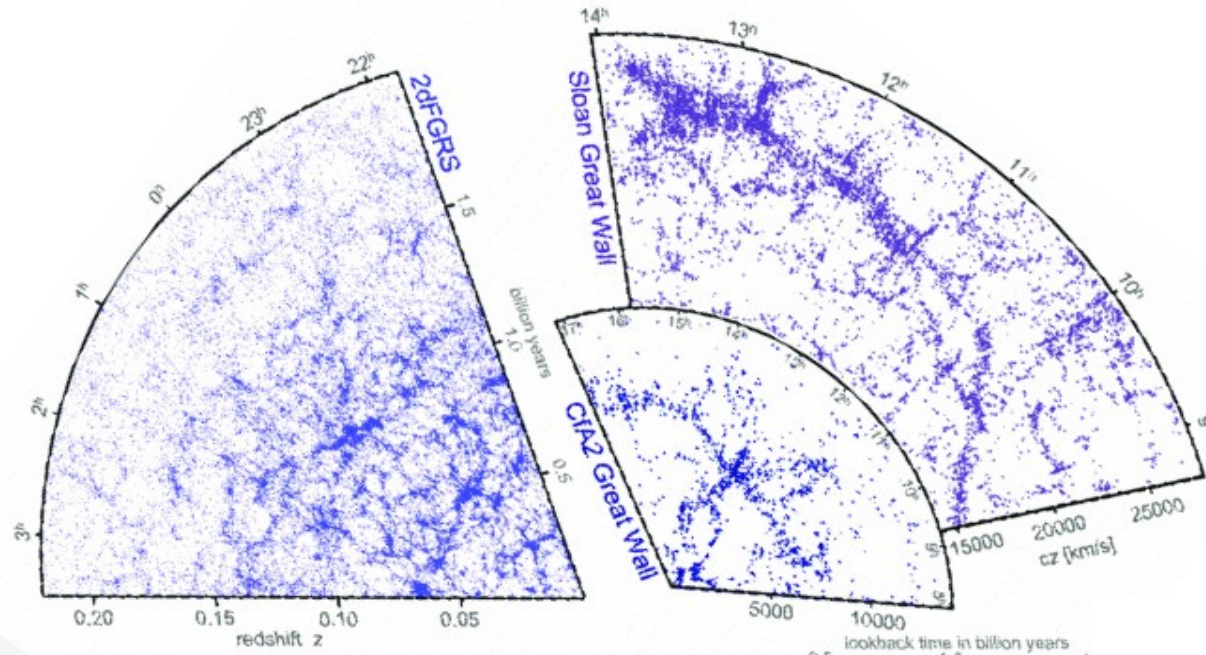
## IV. CMB and nearby galaxies





## **I. The cosmic web**

## Large-Scale Structure (LSS)



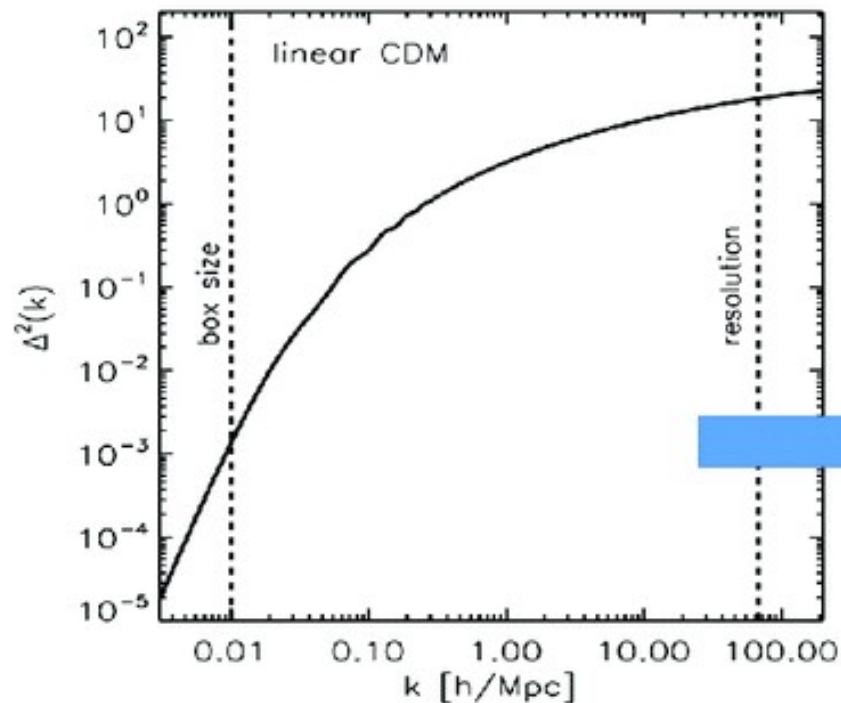
LSS as observed from the first large redshift surveys

First hints of the existence of LSS comes from the analysis of the distribution of “nebulæ”

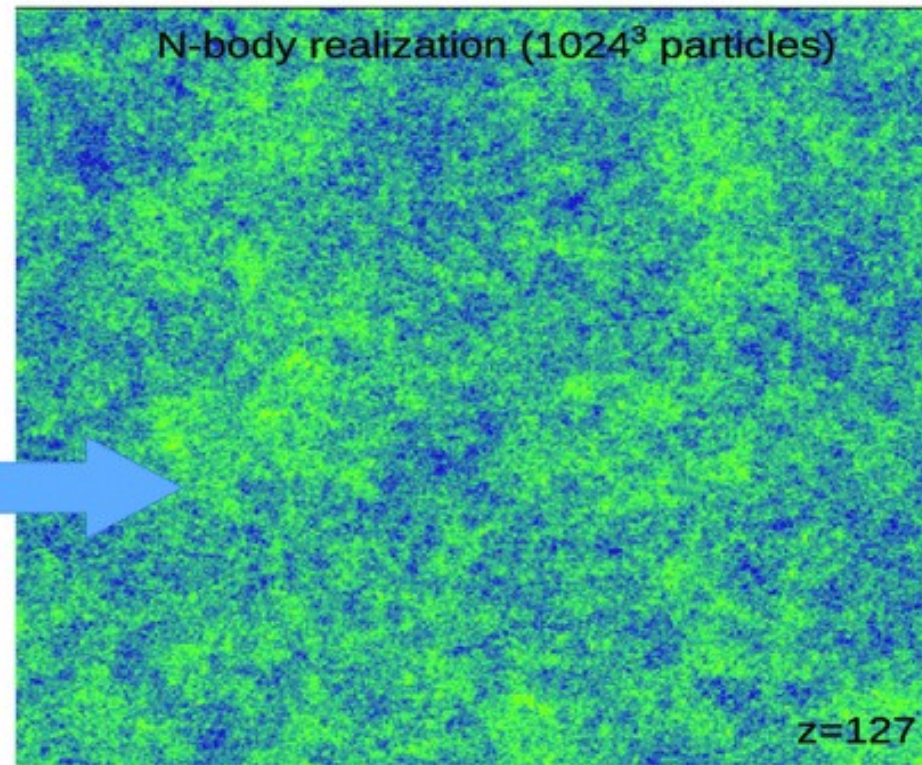
Systematic studies begin with the appearance of redshift surveys



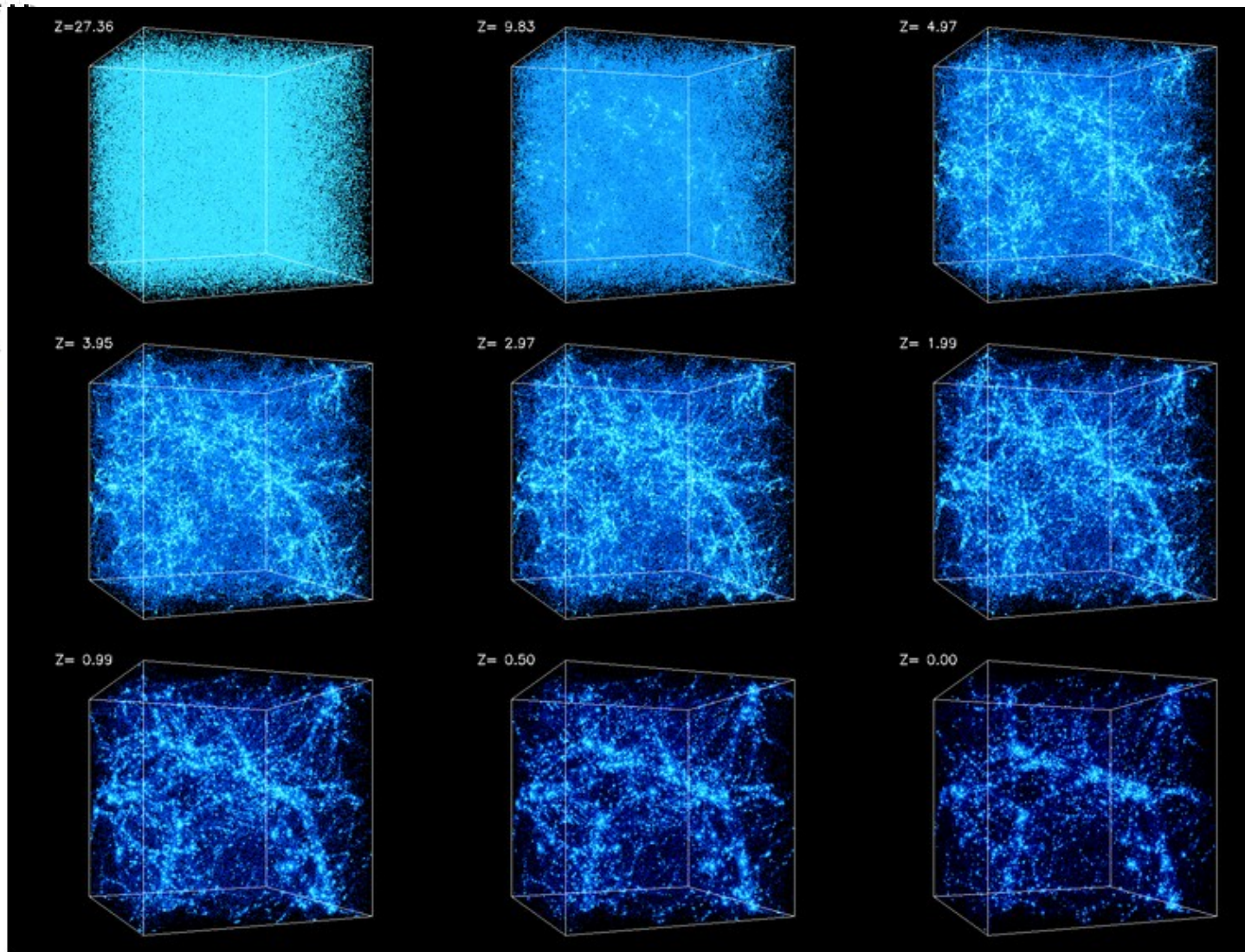
## Large-Scale Structure (LSS)



Input power spectrum for a numerical simulation



(Zavala & Frenk 2019)

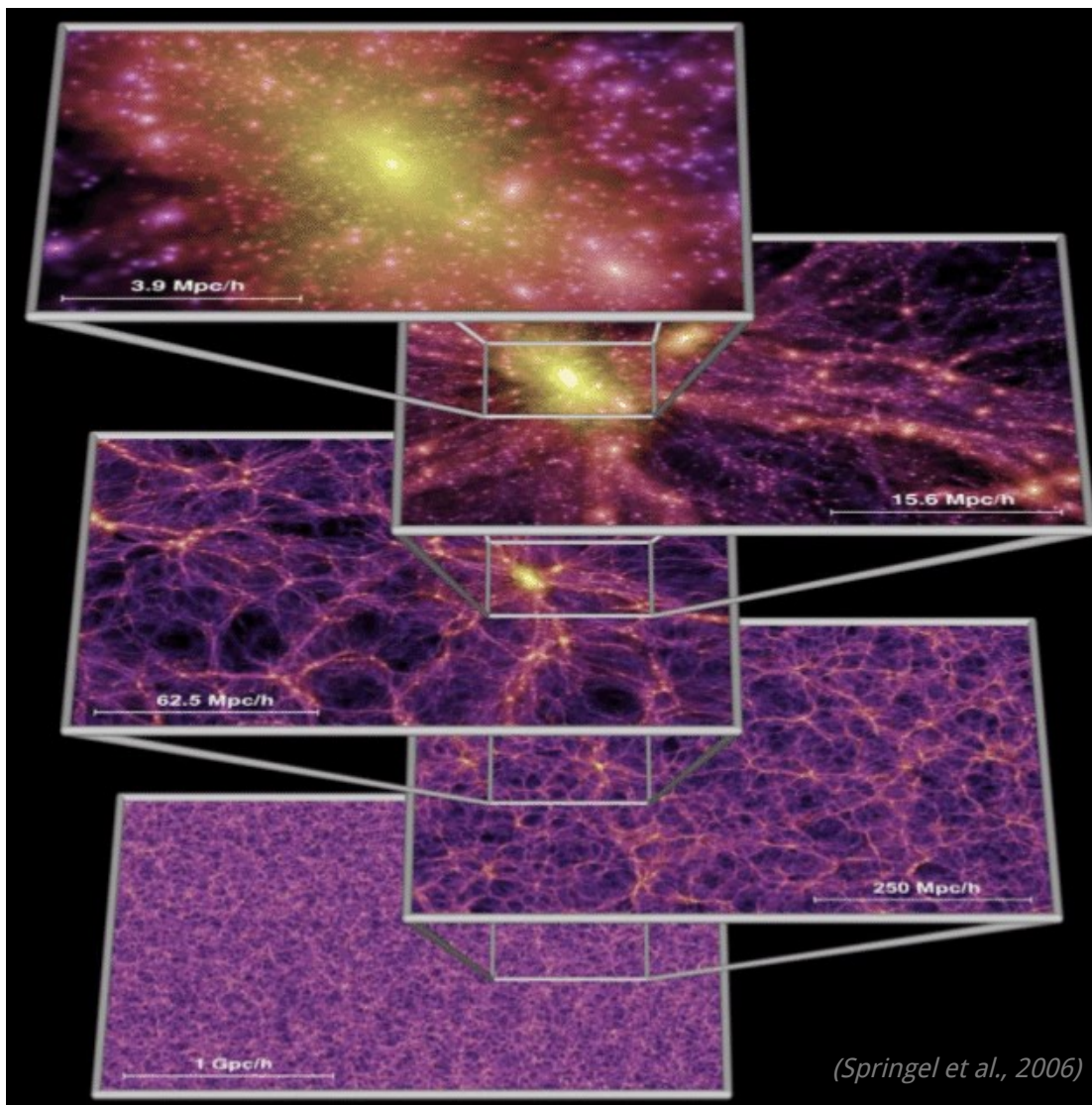


Cosmological numerical simulations constitute the most powerful tool for study the non-linear evolution of matter fluctuations in the Universe

The initial conditions of the simulations are imposed by the input power spectrum, and this is where the cosmological parameters are involved

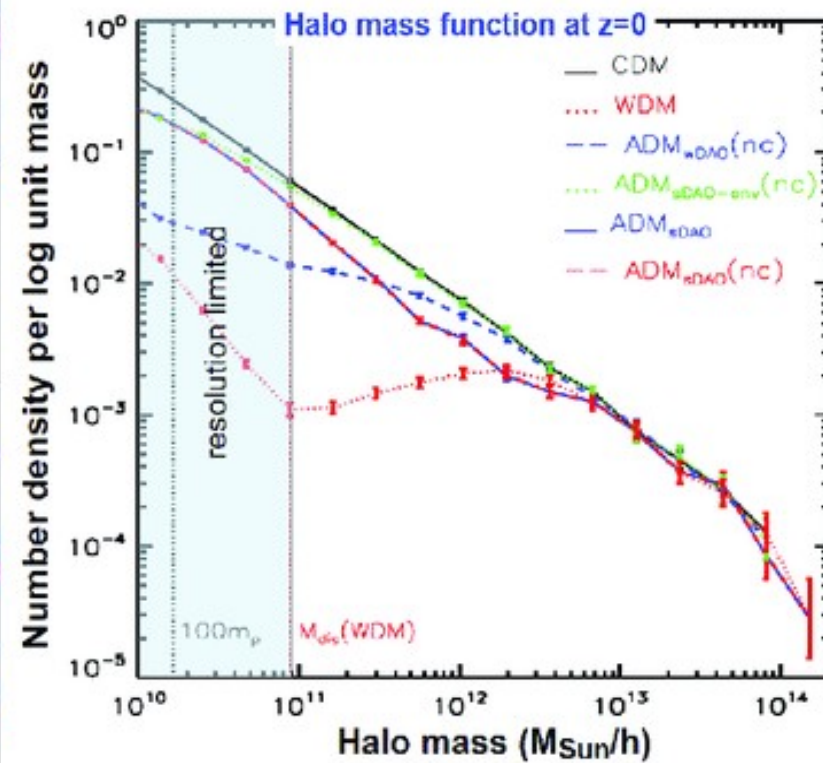
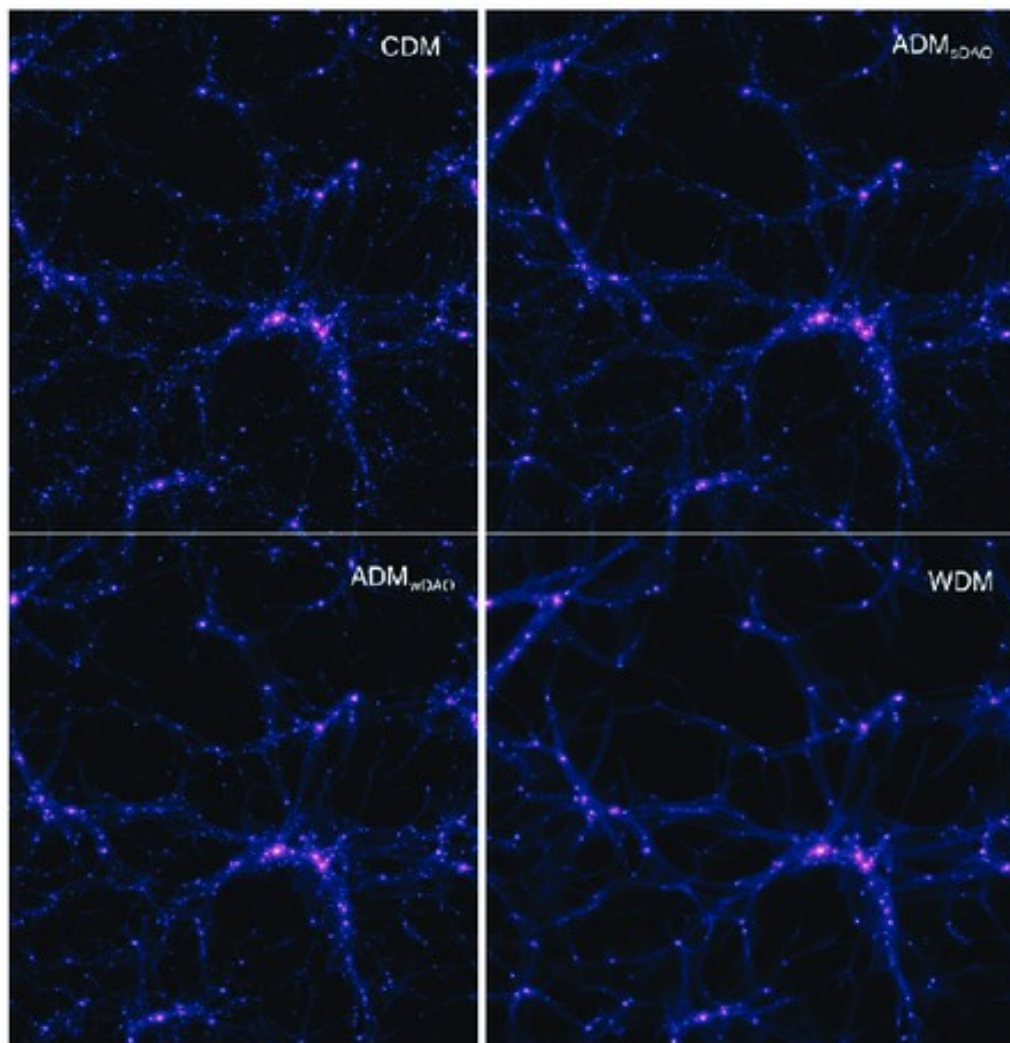
*(Kravtsov & Klypin - web)*





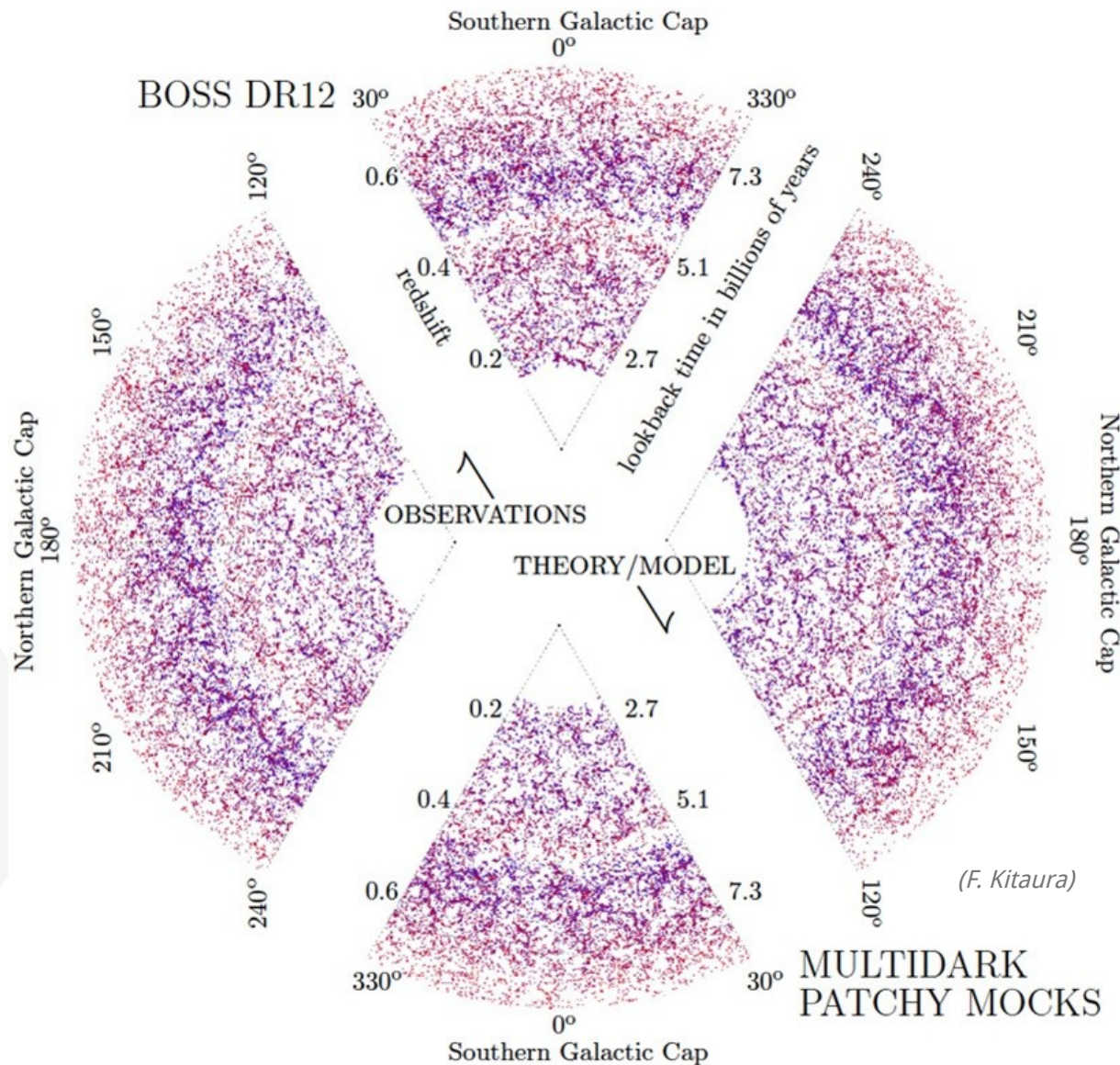
The LSS is clearly present up to scales of about 200 Mpc/h

(Springel et al., 2006)



(Zavala & Frenk 2019)





Results from simulations and observations can not be directly analysed

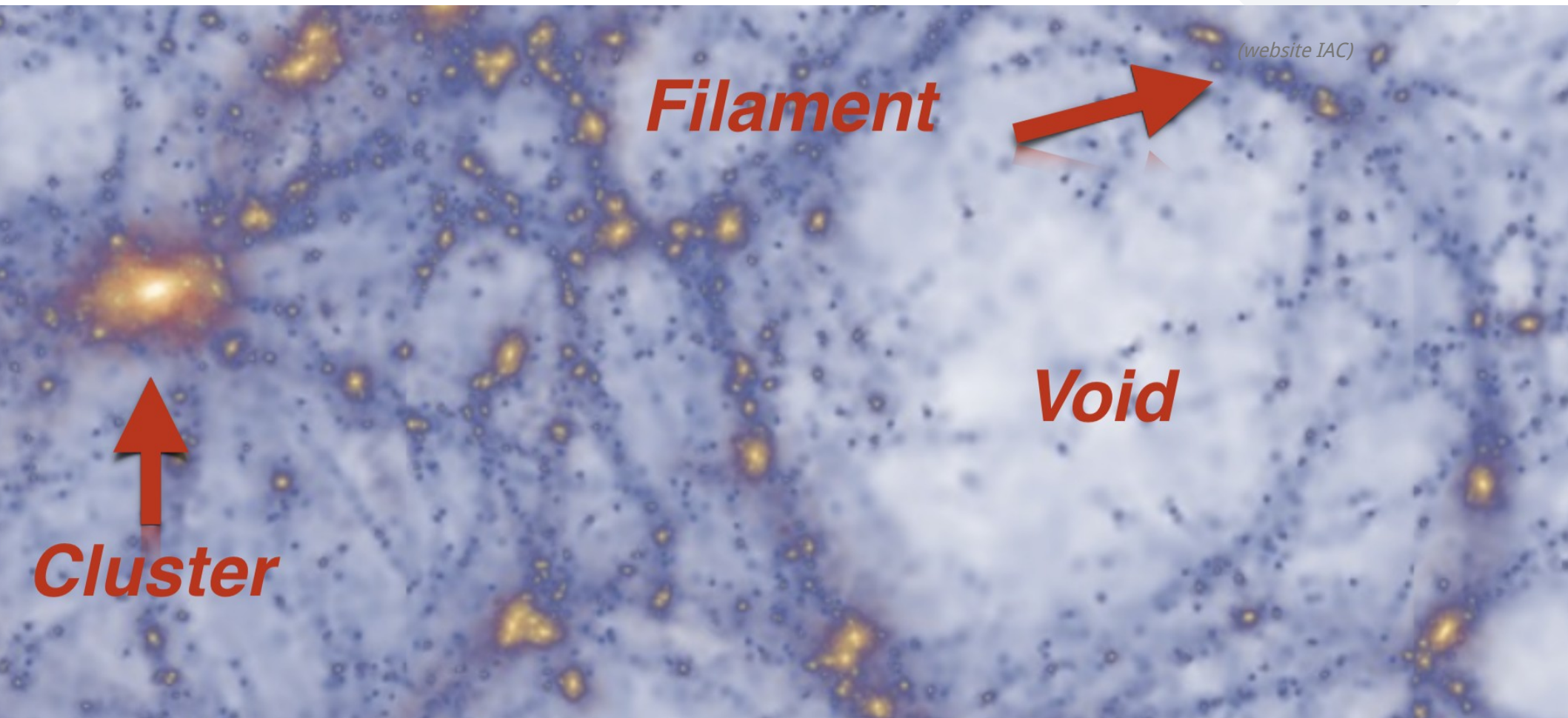
For a proper comparison, it is needed a dark-matter simulation plus a semi-analytical model and the construction of a mock catalogue

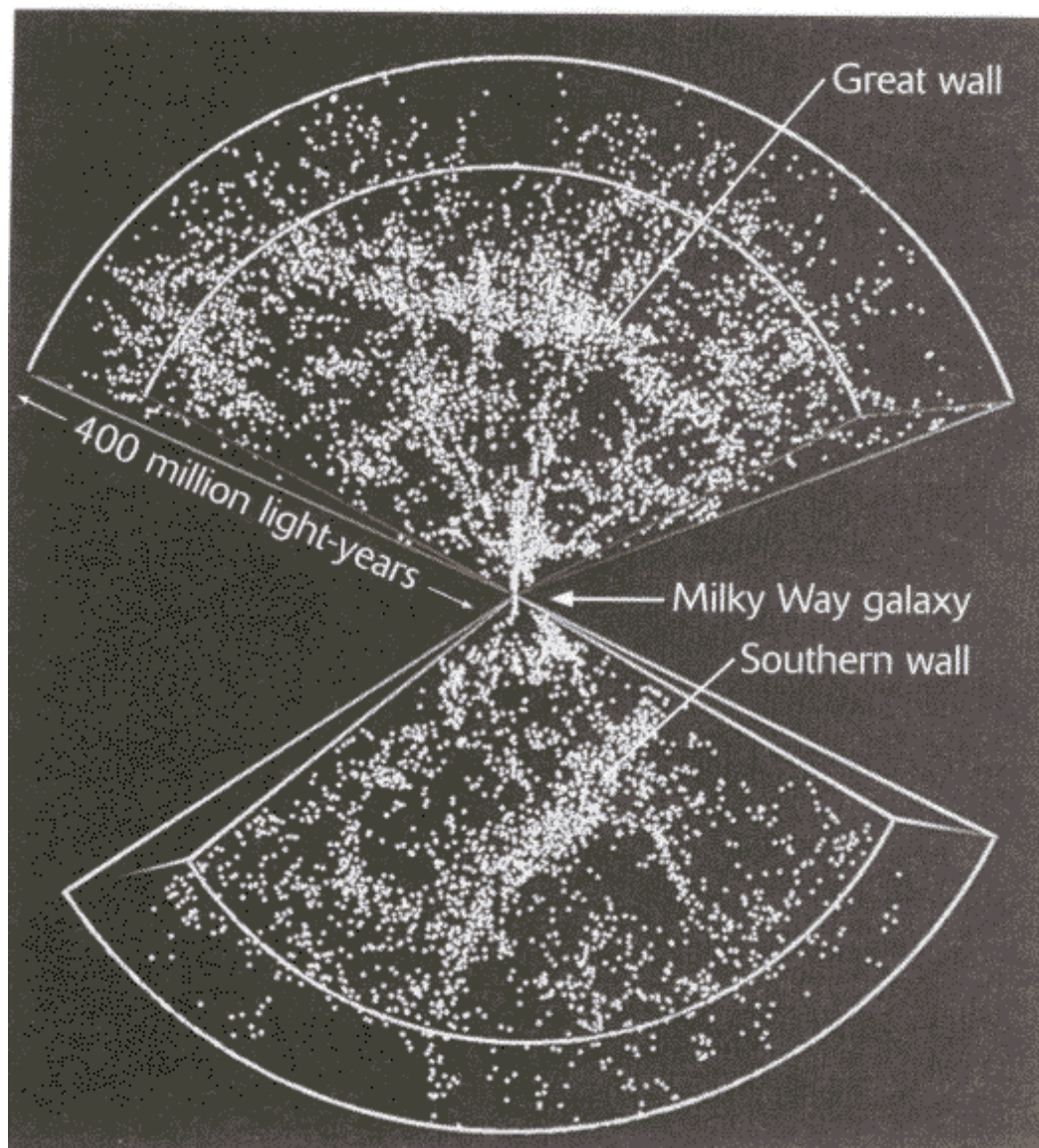


Galaxy Cluster Abell 1689 (Universe Today web page)



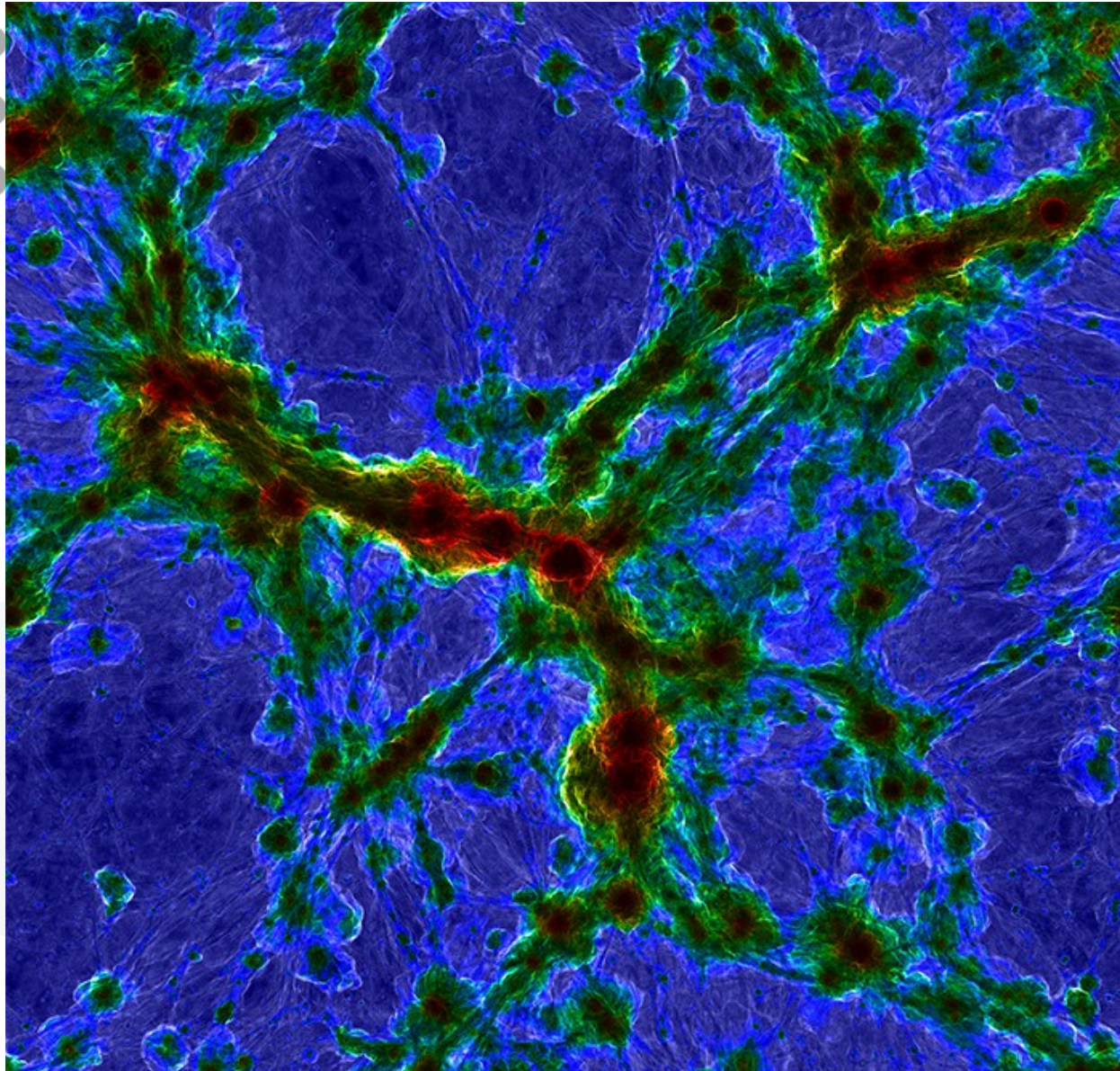
## Large-Scale Structure (LSS)





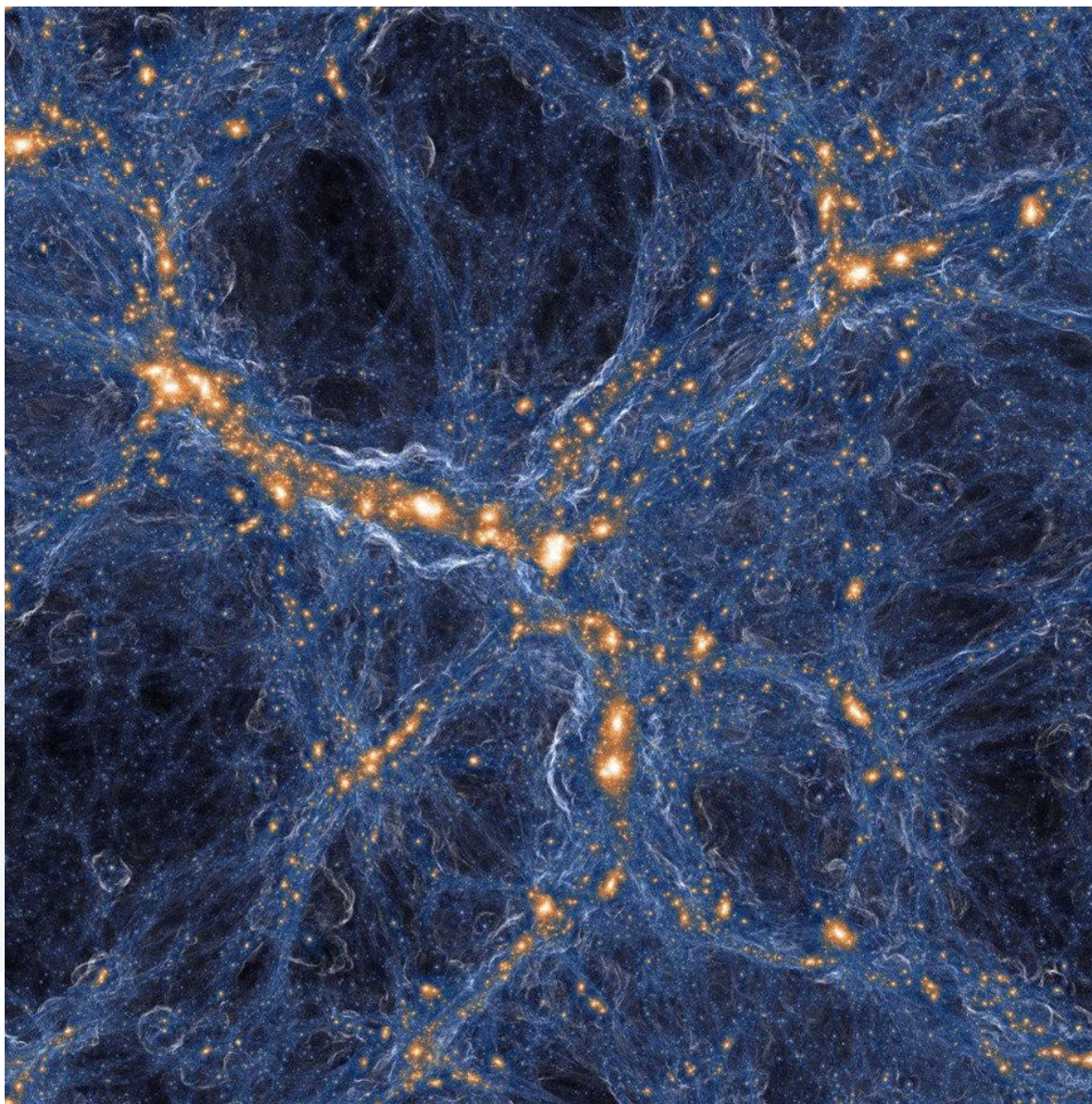
Walls from a slice  
of the SDSS galaxy  
catalogue





Filaments, knots and voids from a slice of the Illustris simulation





Superclusters? of galaxies

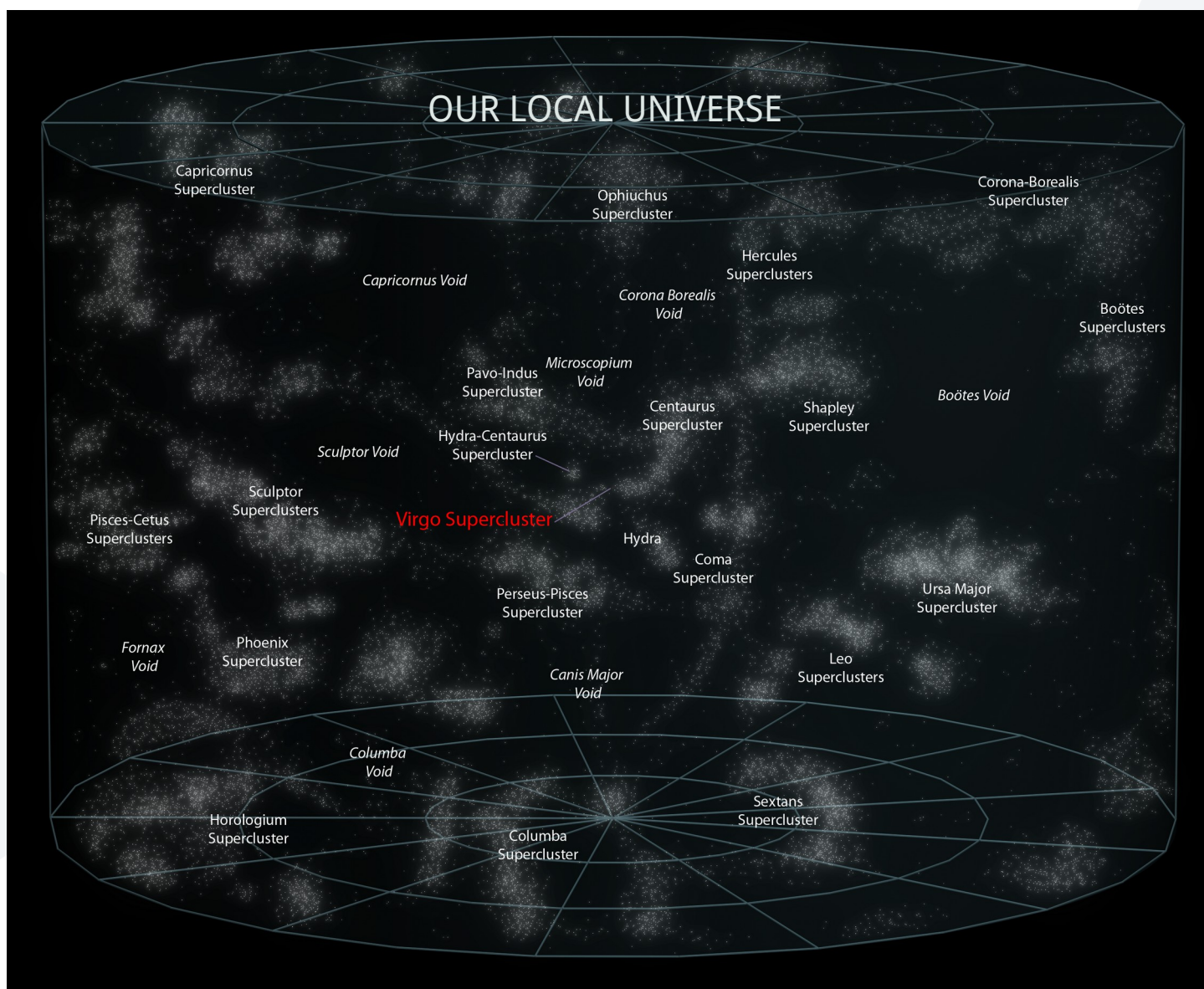
Largest gravitationally bound systems (presently non- virialized) composed by galaxies, groups and clusters.

Dense nuclei with high luminosity galaxies

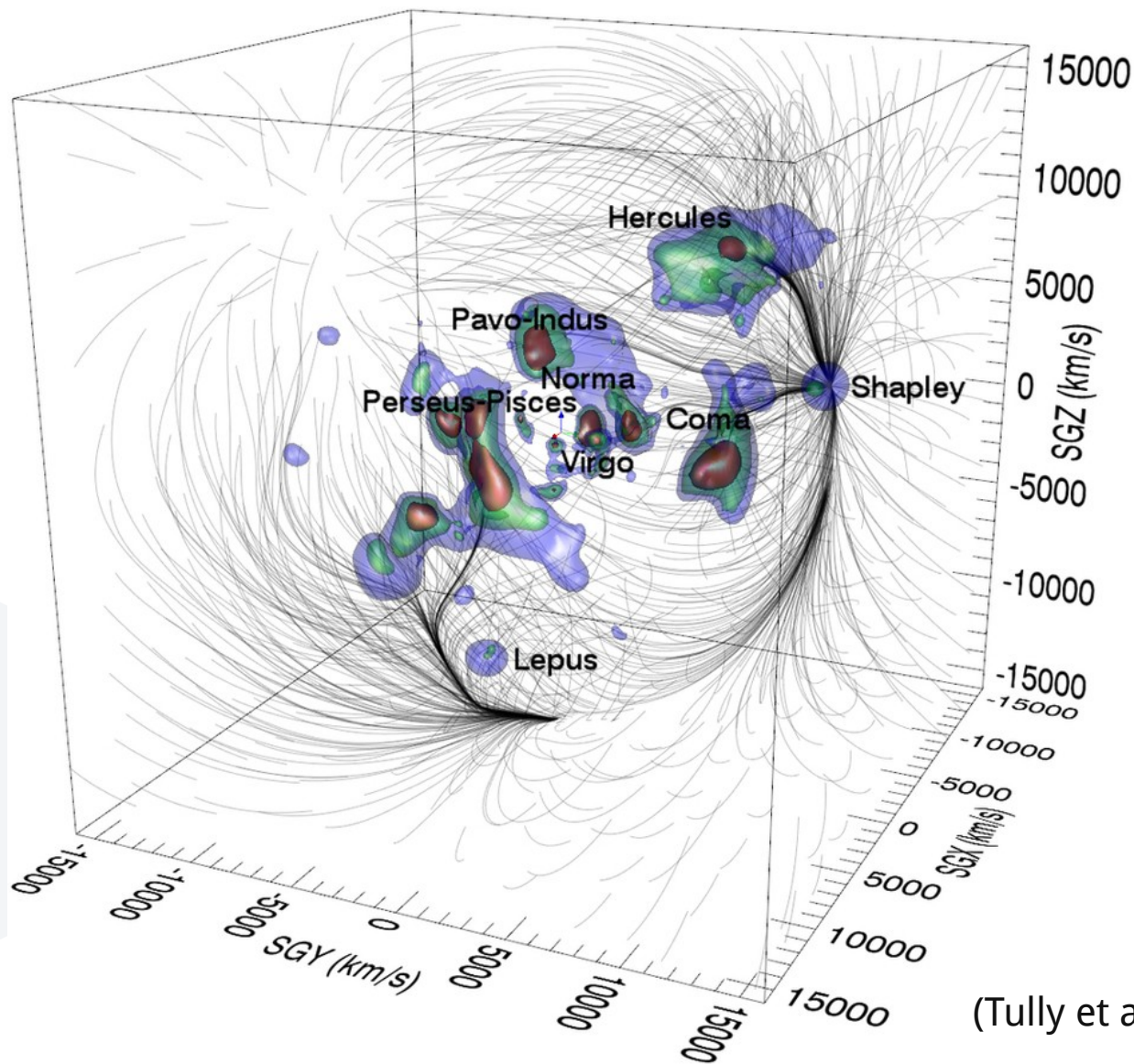
Complex morphology: several filamentary branches

Sizes: 20 to 150 Mpc/h









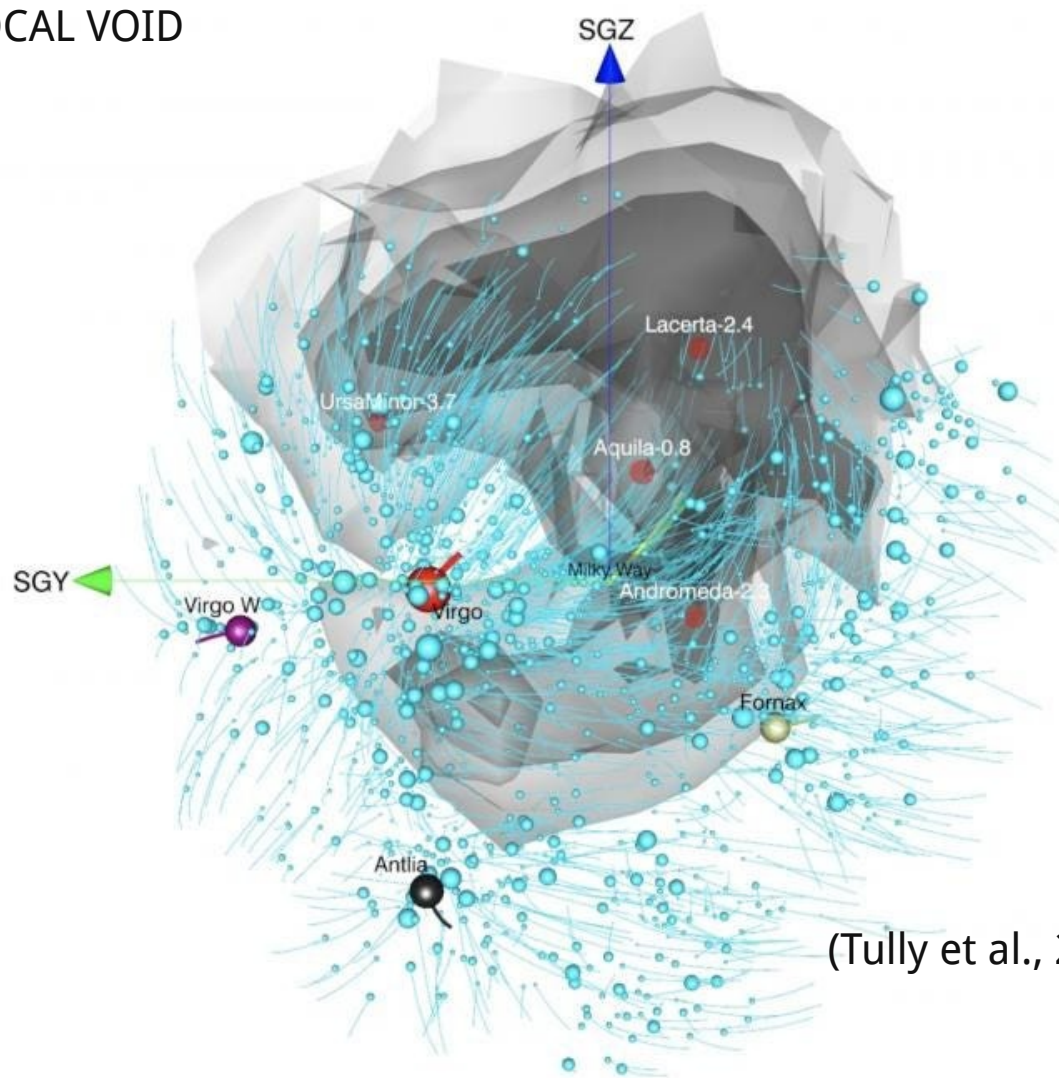
Laniakea Supercluster (Hawaiian for "open skies" or "immense heaven") is home to the Milky Way and approximately 100,000 other nearby galaxies

It is larger than 160 Mpc and  $10^{17}$  solar masses

Consists of four subparts, which were known previously as separate superclusters.

(Tully et al., 2014)

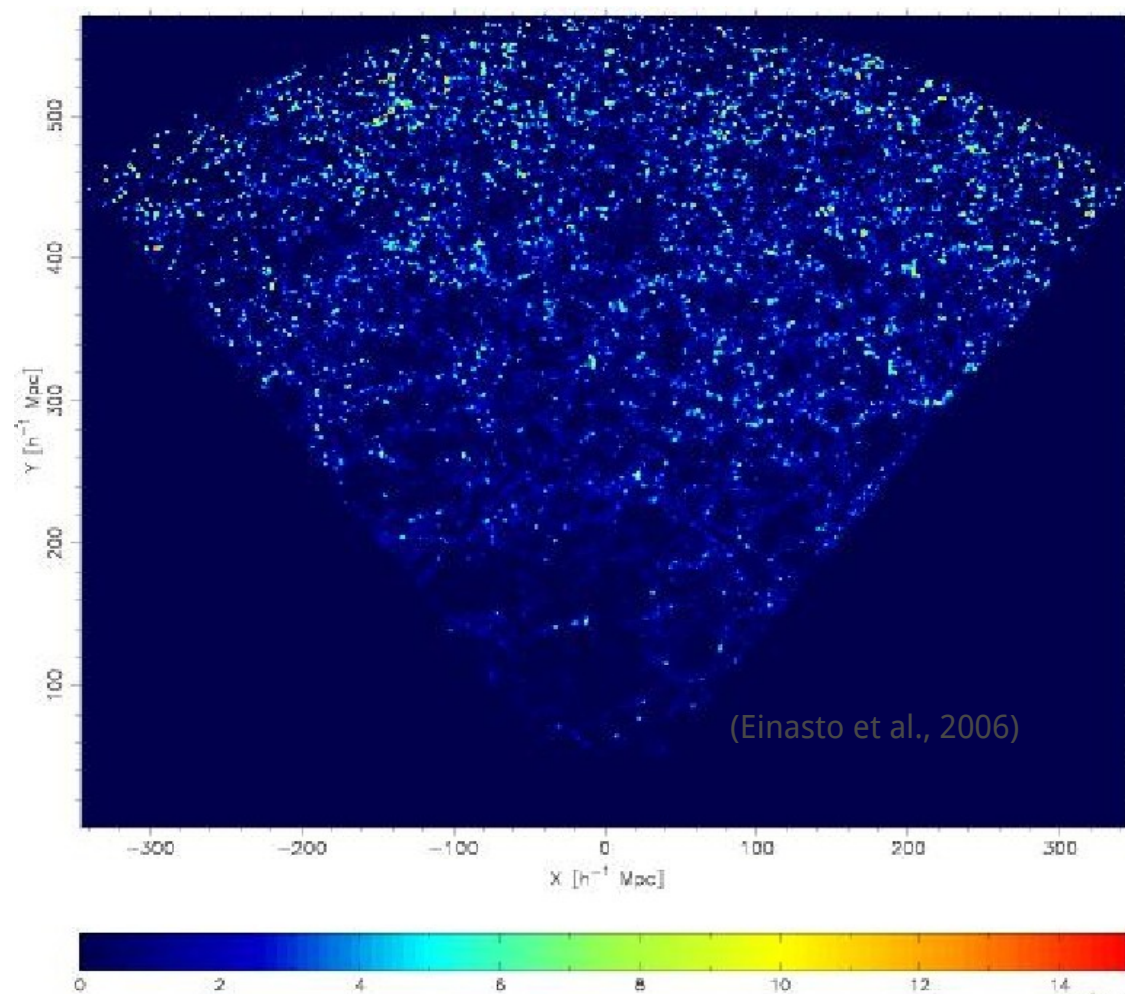
## LOCAL VOID



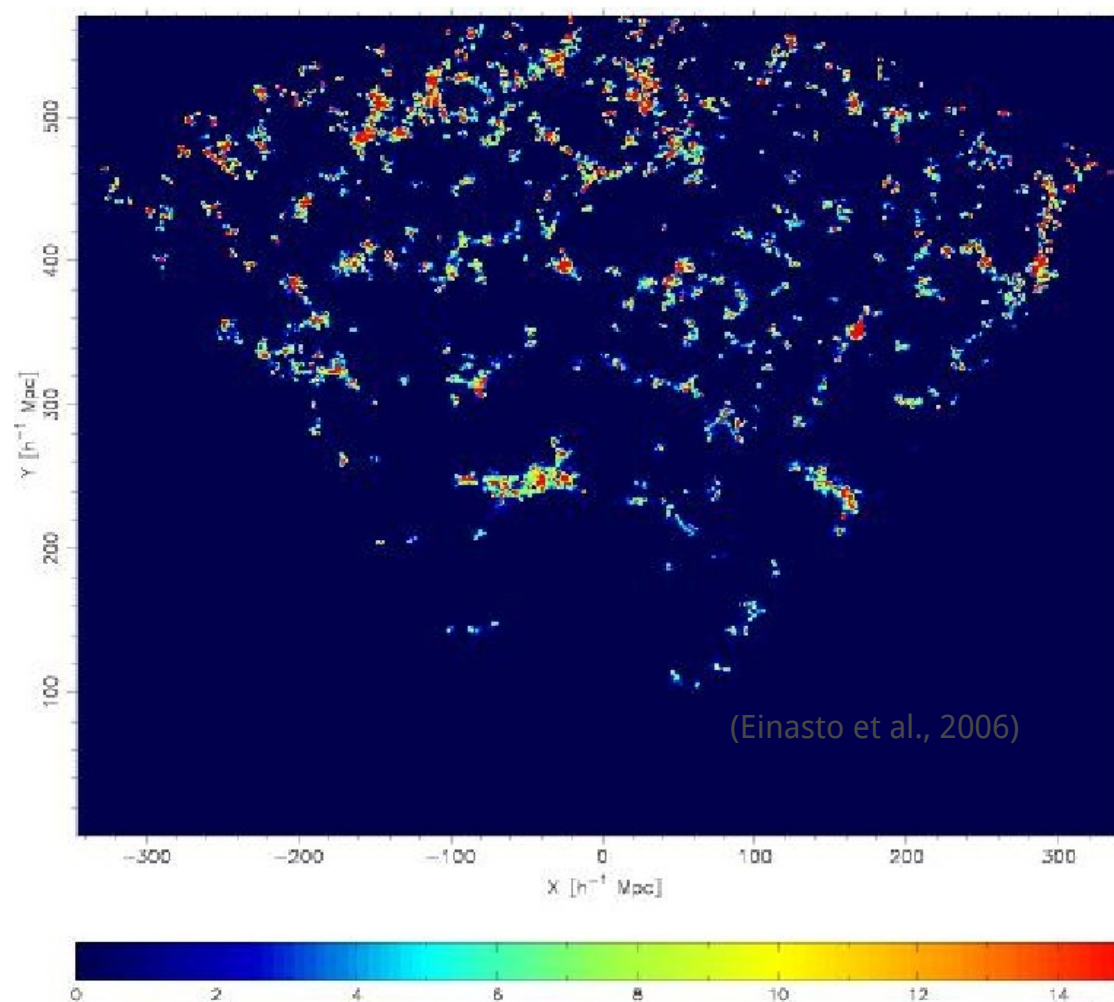
(Tully et al., 2019)



## Identification of Large-Scale Structures

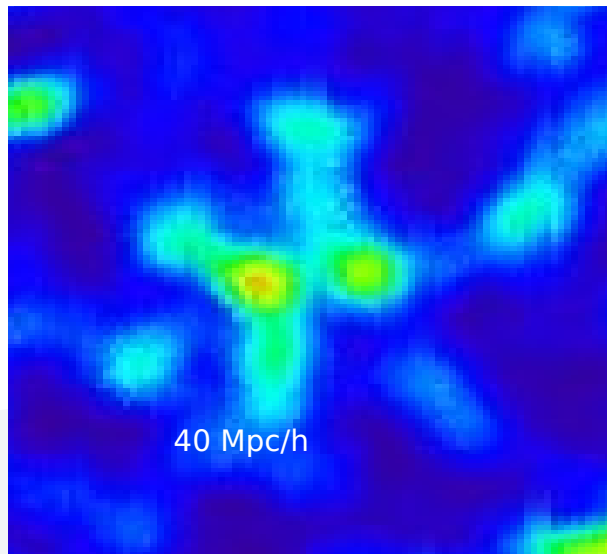


## Identification of Large-Scale Structures

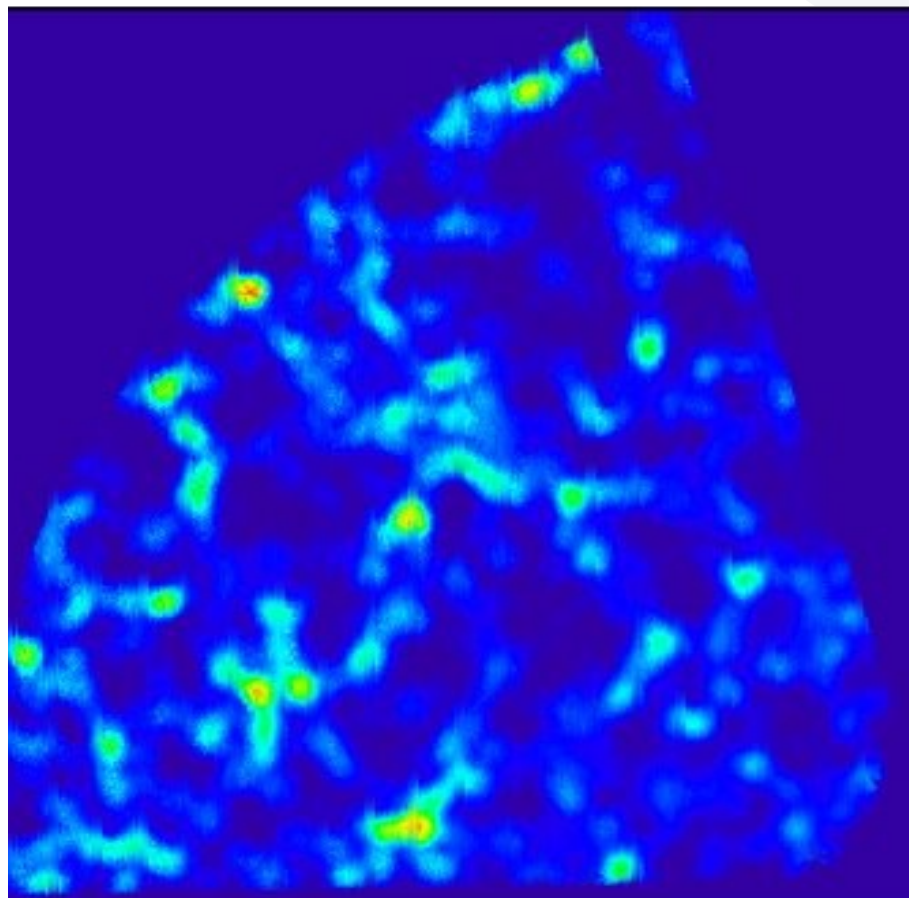




## Identification of superstructures (or FVS)

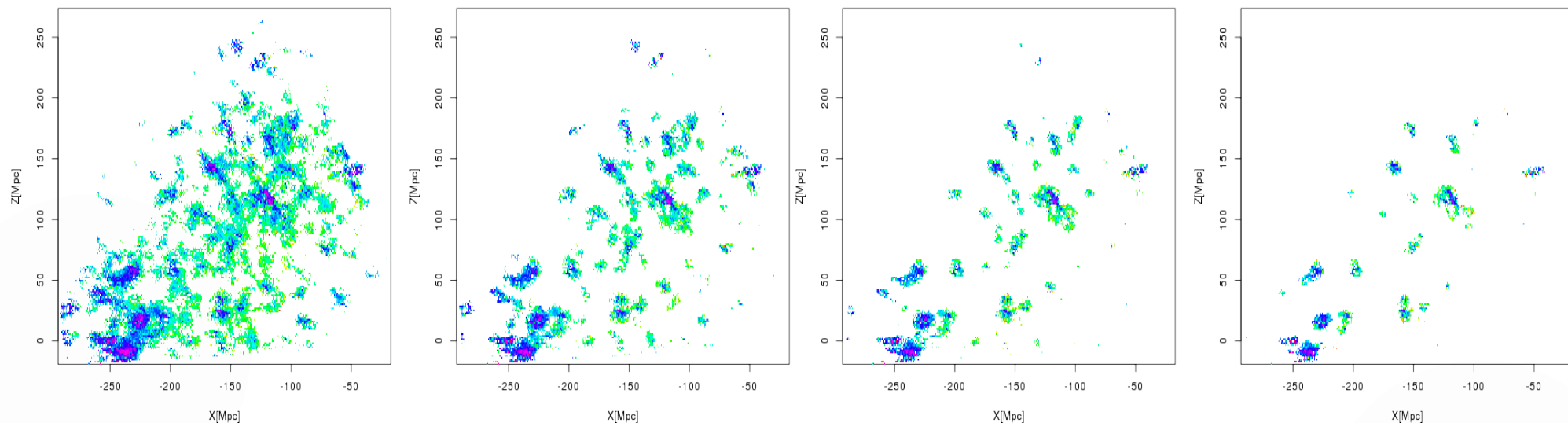


Slice of the luminosity density field from  
the SDSS



## Identification of superstructures (or FVS)

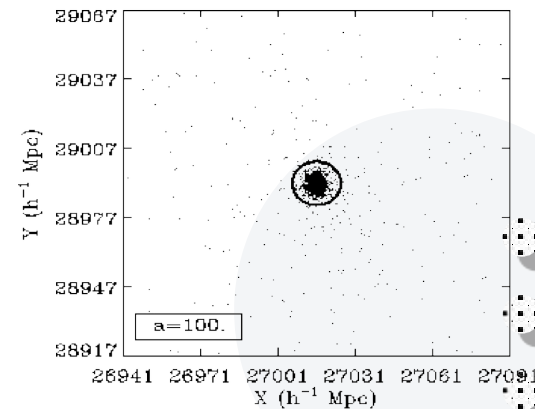
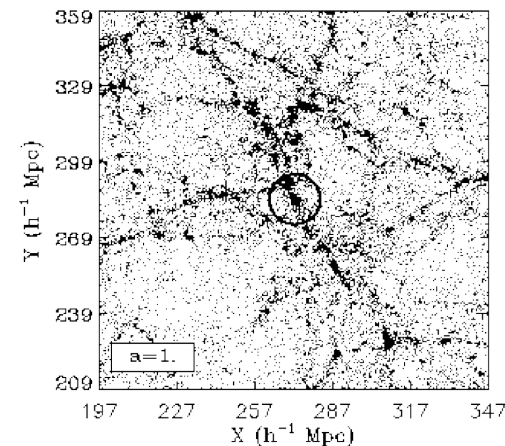
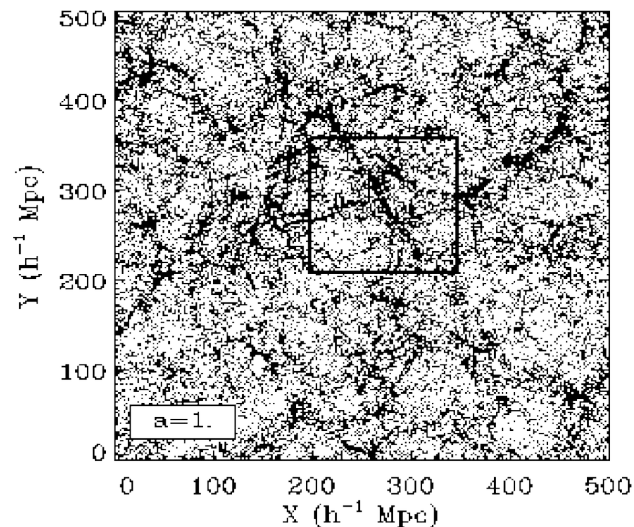
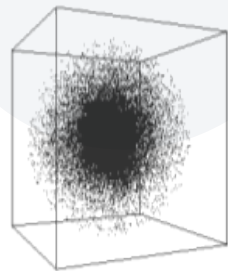
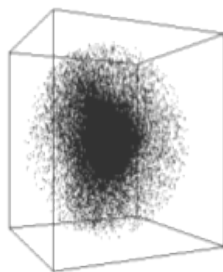
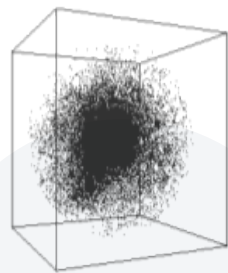
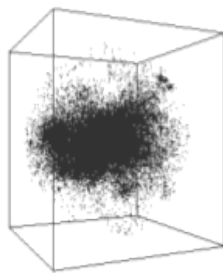
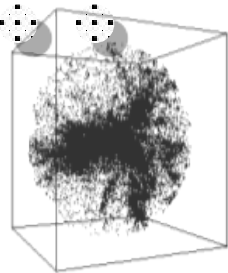
Luminosity threshold variation



**As superclusters are not in dynamical equilibrium, we can not use theoretical arguments to fix the luminosity density threshold**

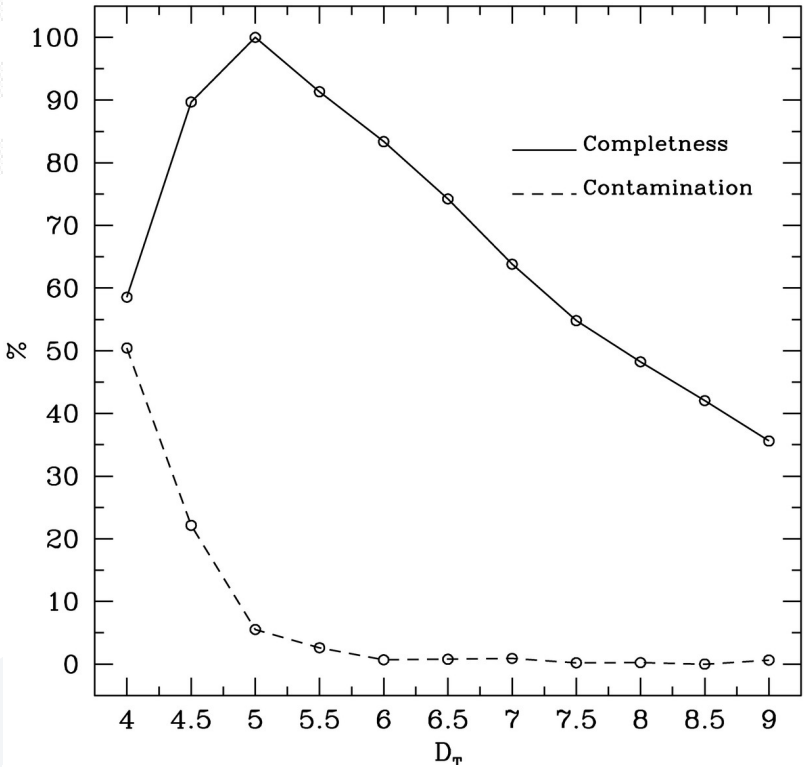
Spherical collapse model in  $\Lambda$ CDM + numerical simulations:*Dünner et al. (2006), Araya-Melo et al (2009)*

$\bar{\rho}_{\text{mass-shell}} \geq 7,8 \rho_{\text{bck}} \rightarrow$  superstructures that remain bound to  $a(t) = 100$ .



(72% of the particles remain bound and have 0.3% of contamination)





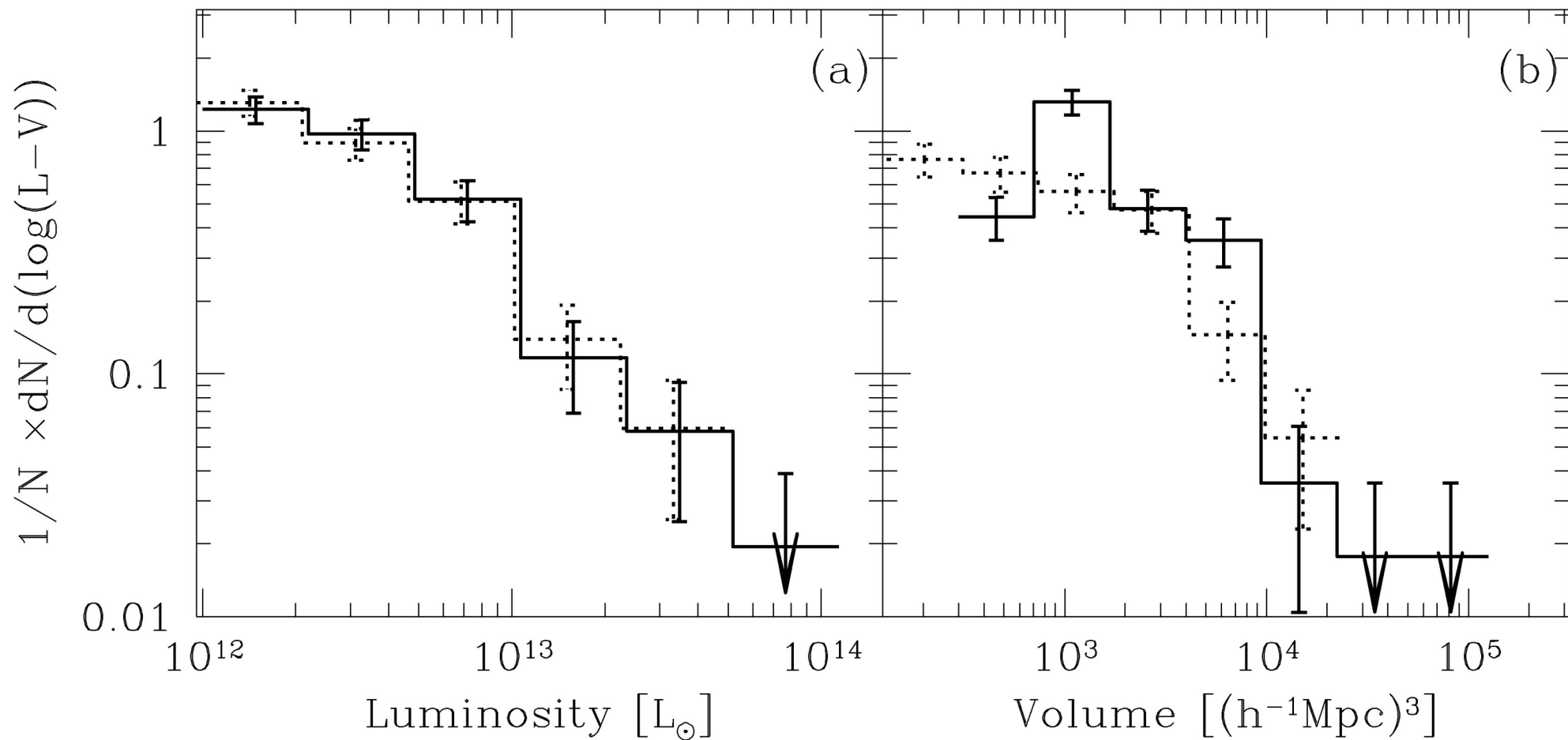
# Superstructure catalogue based on SDSS-DR7 data

Completeness: ratio of the number of structures for a given  $D_{thr}$  over the maximum number of structures in the  $D_{thr}$  range.

Contamination: fraction of the structures that do no satisfy the mass criteria.

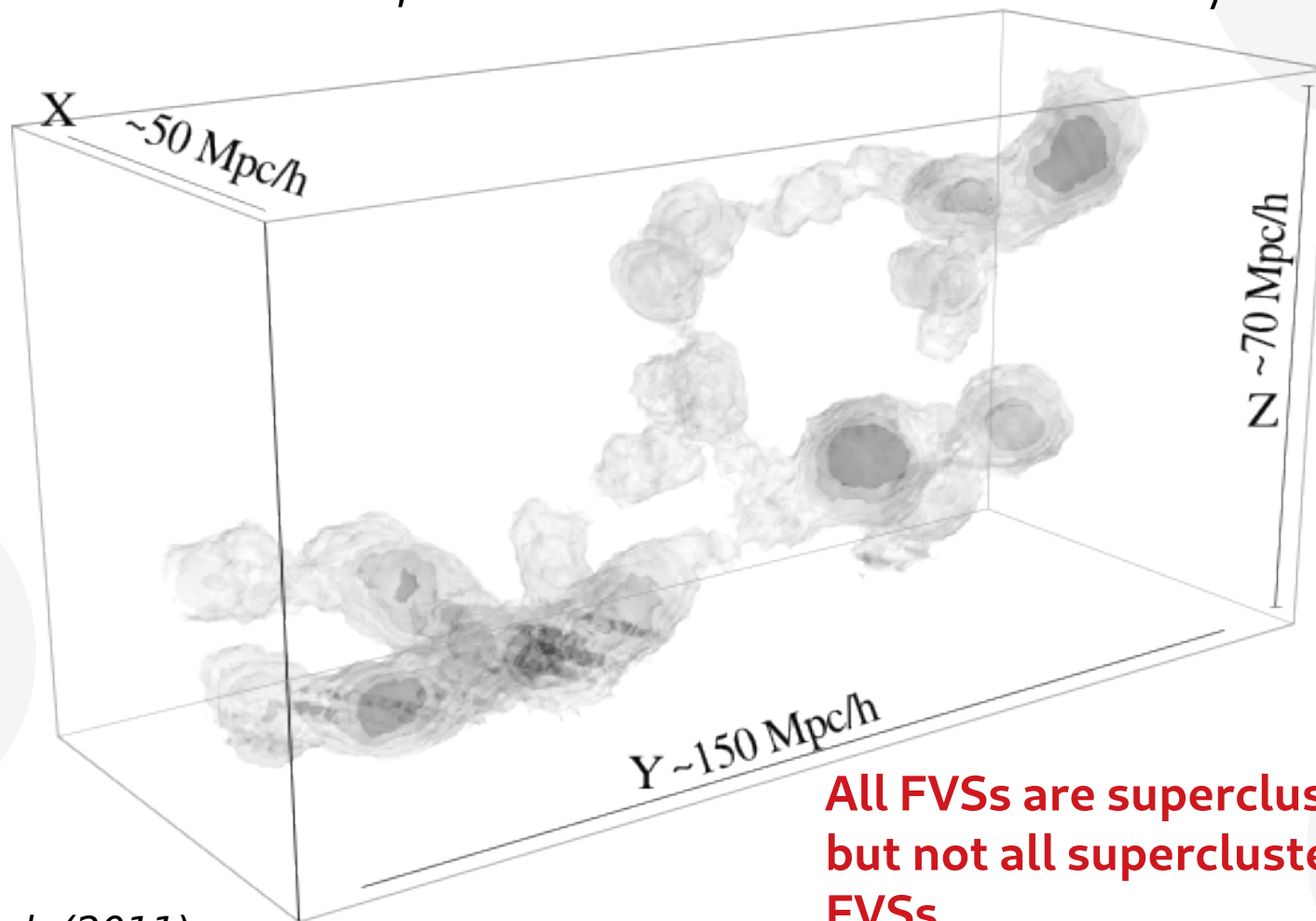
| Sample    | $z_{max}$ | $D_{max}[h^{-1} Mpc]$ | $M_r^{lim}$ | Volume [ $10^7 (h^{-1} Mpc)^3$ ] | $N_{gal}$ |
|-----------|-----------|-----------------------|-------------|----------------------------------|-----------|
| S1        | 0.10      | 293.92                | -20.05      | 1.85                             | 94271     |
| S2        | 0.12      | 351.34                | -20.47      | 3.17                             | 89513     |
| S3        | 0.15      | 436.55                | -21.00      | 6.01                             | 62344     |
| S2c       | 0.10      | 293.92                | -20.47      | 1.85                             | 51188     |
| S3c       | 0.10      | 293.92                | -21.00      | 1.85                             | 17507     |
| $M_{Rsp}$ | 0.12      | 351.34                | -20.47      | 3.17                             | 106604    |

| Sample    | $N_{FVS}$ | $F_{vol}$ | $F_{lum}$ | $glx_{sinFVS}$ |
|-----------|-----------|-----------|-----------|----------------|
| S1        | 67        | 1.08%     | 10.85%    | 9707           |
| S2        | 150       | 1.26%     | 13.54%    | 11394          |
| S3        | 412       | 1.66%     | 20.61%    | 11682          |
| $M_{Rsp}$ | 227       | 1.62%     | 18.87%    | 19265          |
| $M_{Zsp}$ | 181       | 1.35%     | 15.14%    | 15368          |



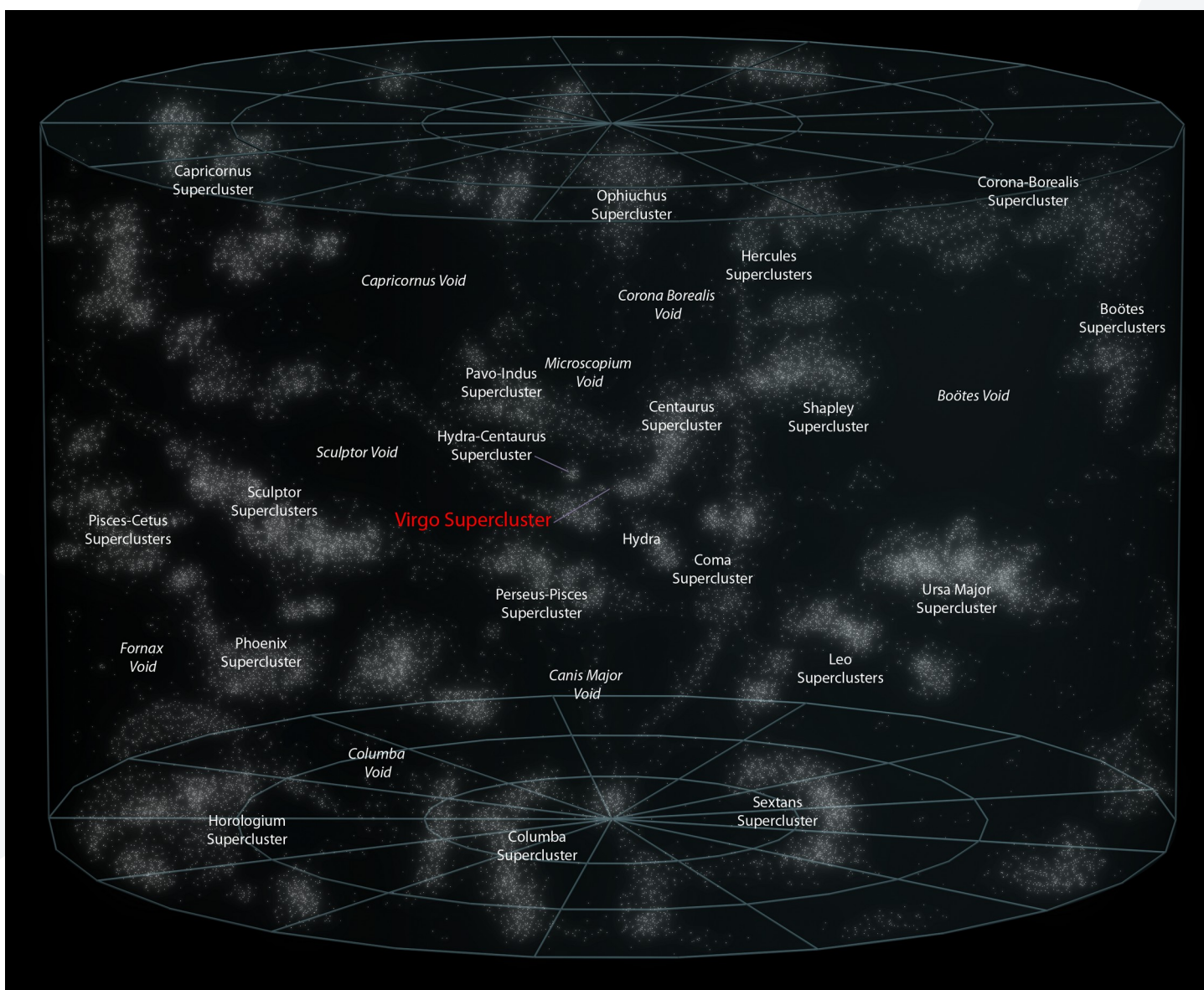
Volume and Luminosity distributions of FVSs compared to Liivamagi superclusters

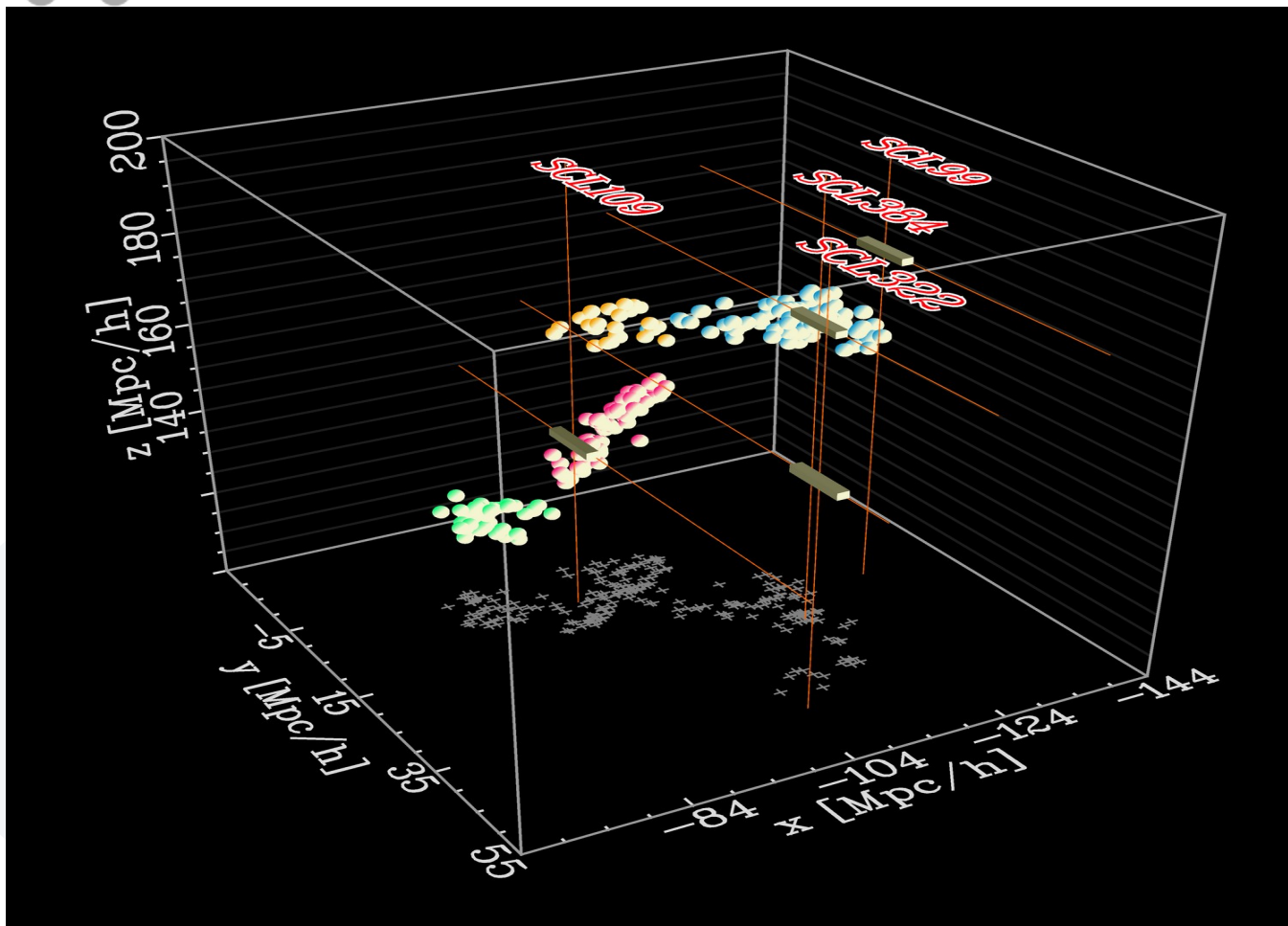
In the LCDM framework, FVSs will be isolated and virialized systems in the future



**All FVSs are superclusters,  
but not all superclusters are  
FVSs**



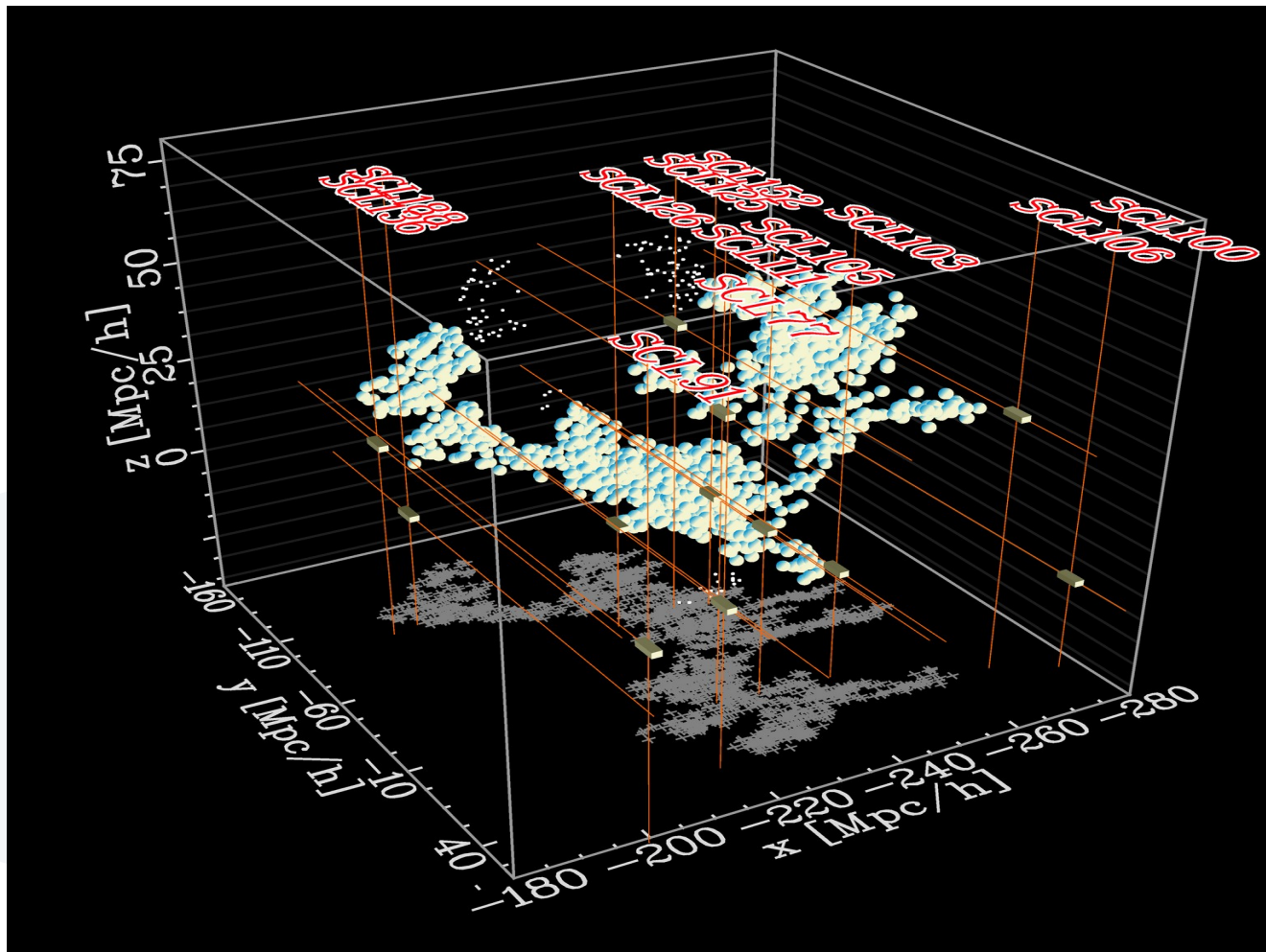




## URSA MAJOR SCL

Composed by three large filaments (Kopylova & Kopylov, 2006)

**We find a different FVS associated to each filament, suggesting that this SCL would evolve into separate structures.**

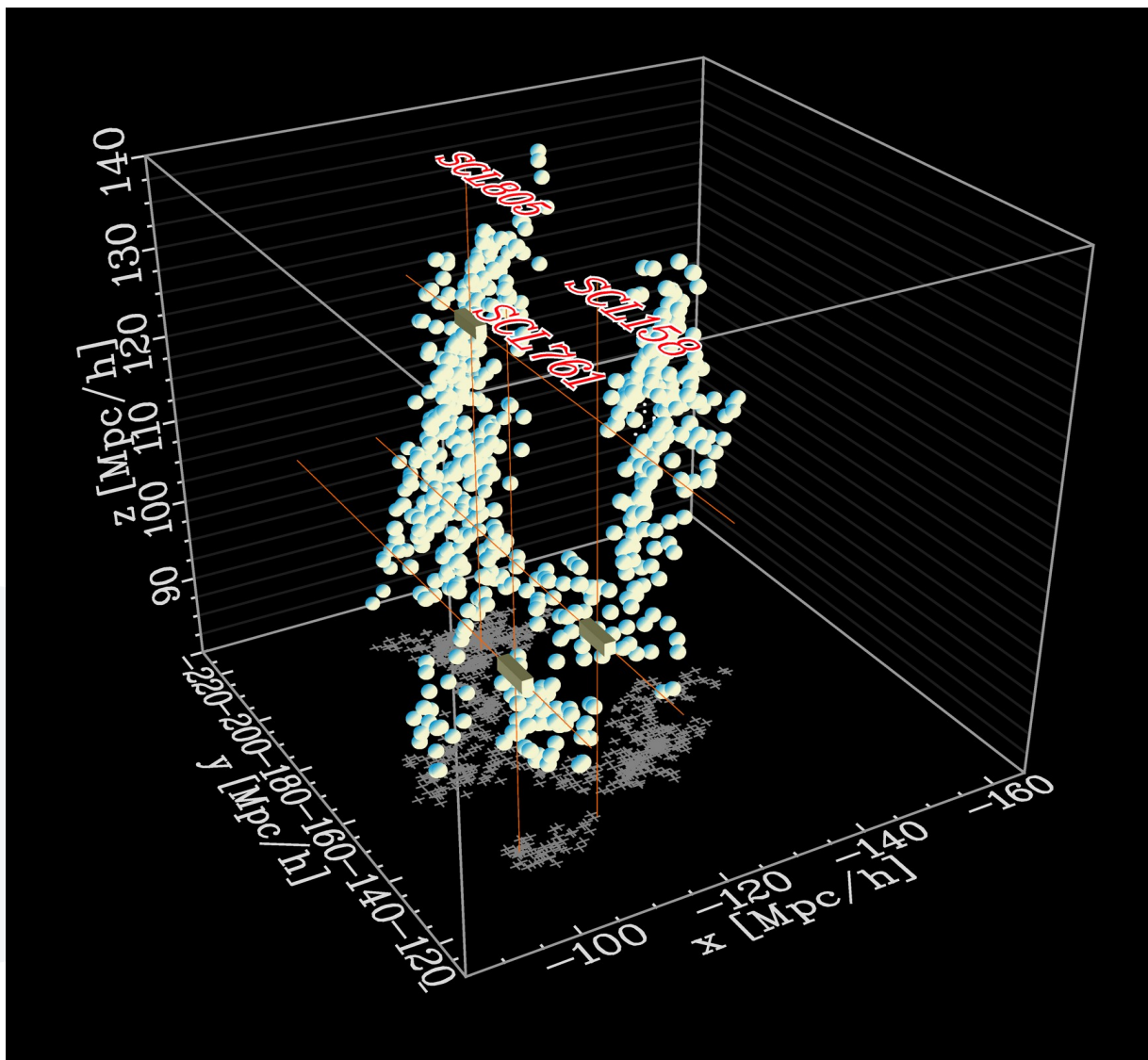


## SLOAN GREAT WALL

We identify a single FVS comprising several known SCL in the Sloan GG.

These SCLs may evolve into a single virialized system.

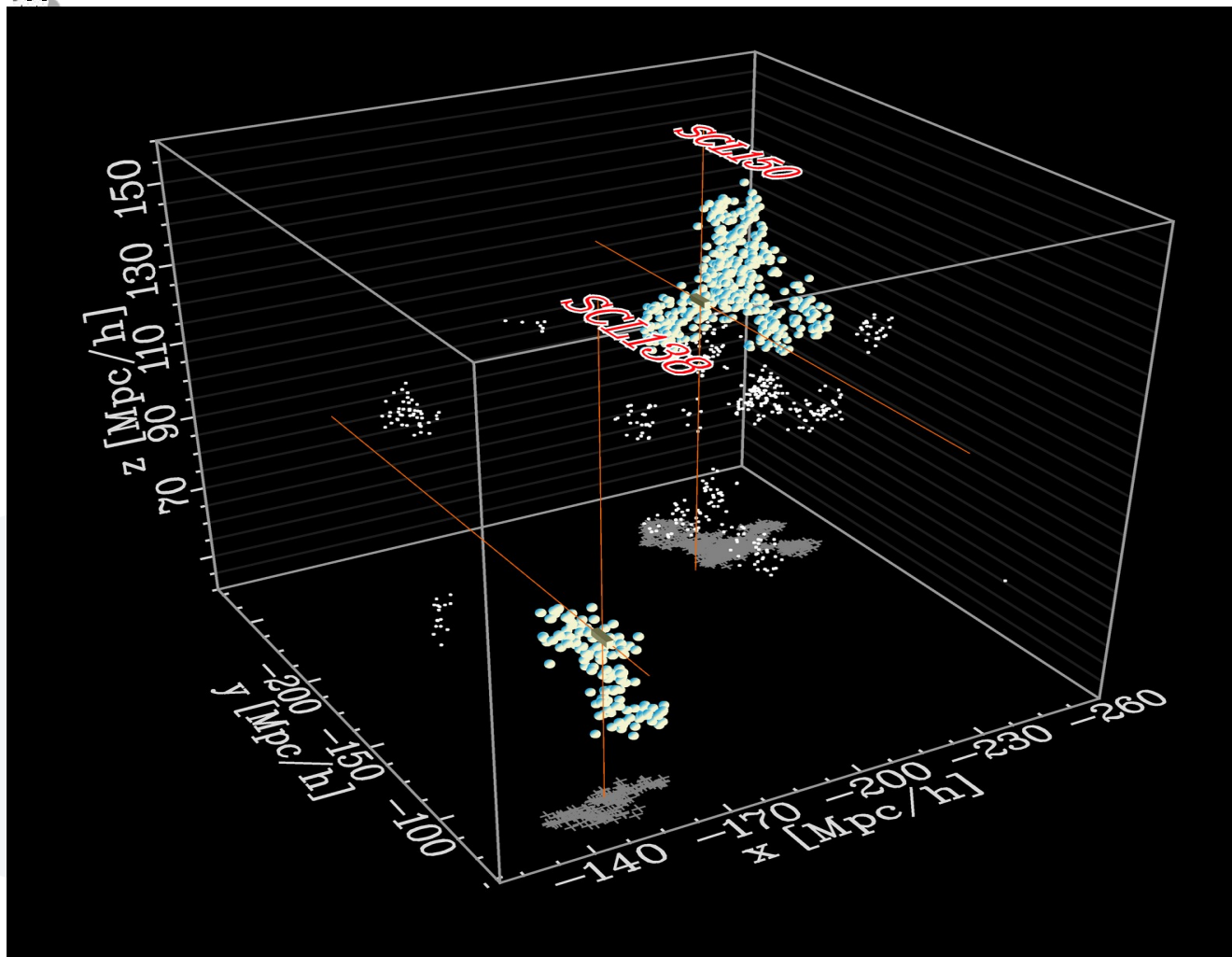




## CORONA BOREALIS SCL158

SCL158 is part of a large FVS that also includes SCL805 y SCL761.

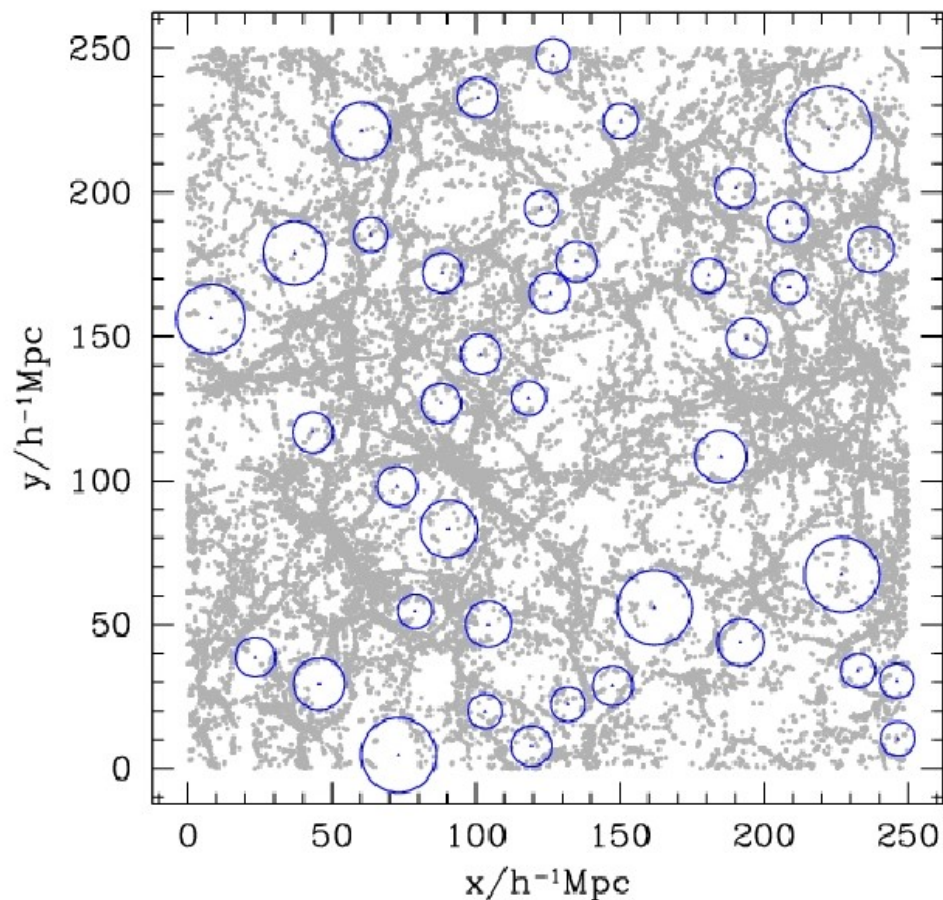
These three systems could merge to form a single virialized structure in the future.



## BOOTES SCLS

Have one to one  
correspondence  
with FVS, so each  
system would evolve  
into a FVS.

## Identification of voids



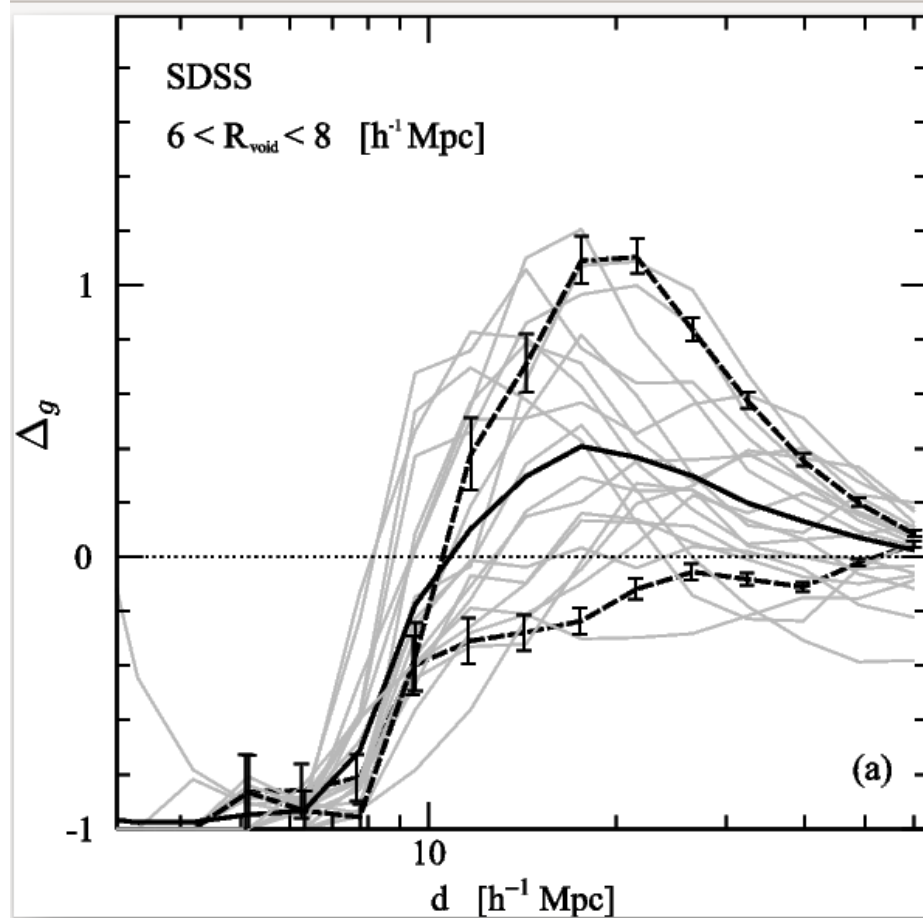
It is assumed that voids are approximately spherical

Voids are defined as the largest spherical volume within which the matter density is below of less than 10% of the mean density

(Ceccarelli et al., 2008)



## Numerical density profiles of stacked void sample

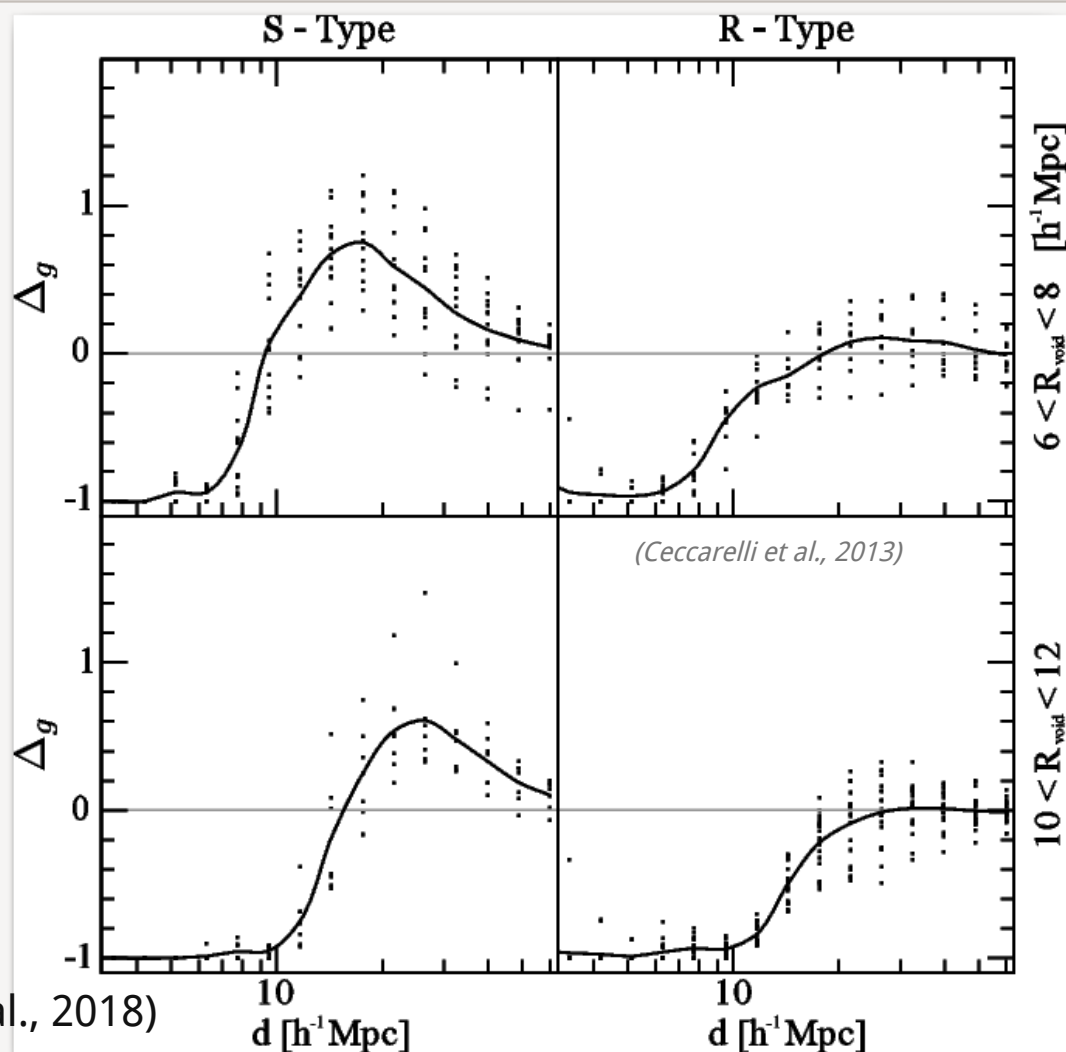


(Ceccarelli et al., 2018)

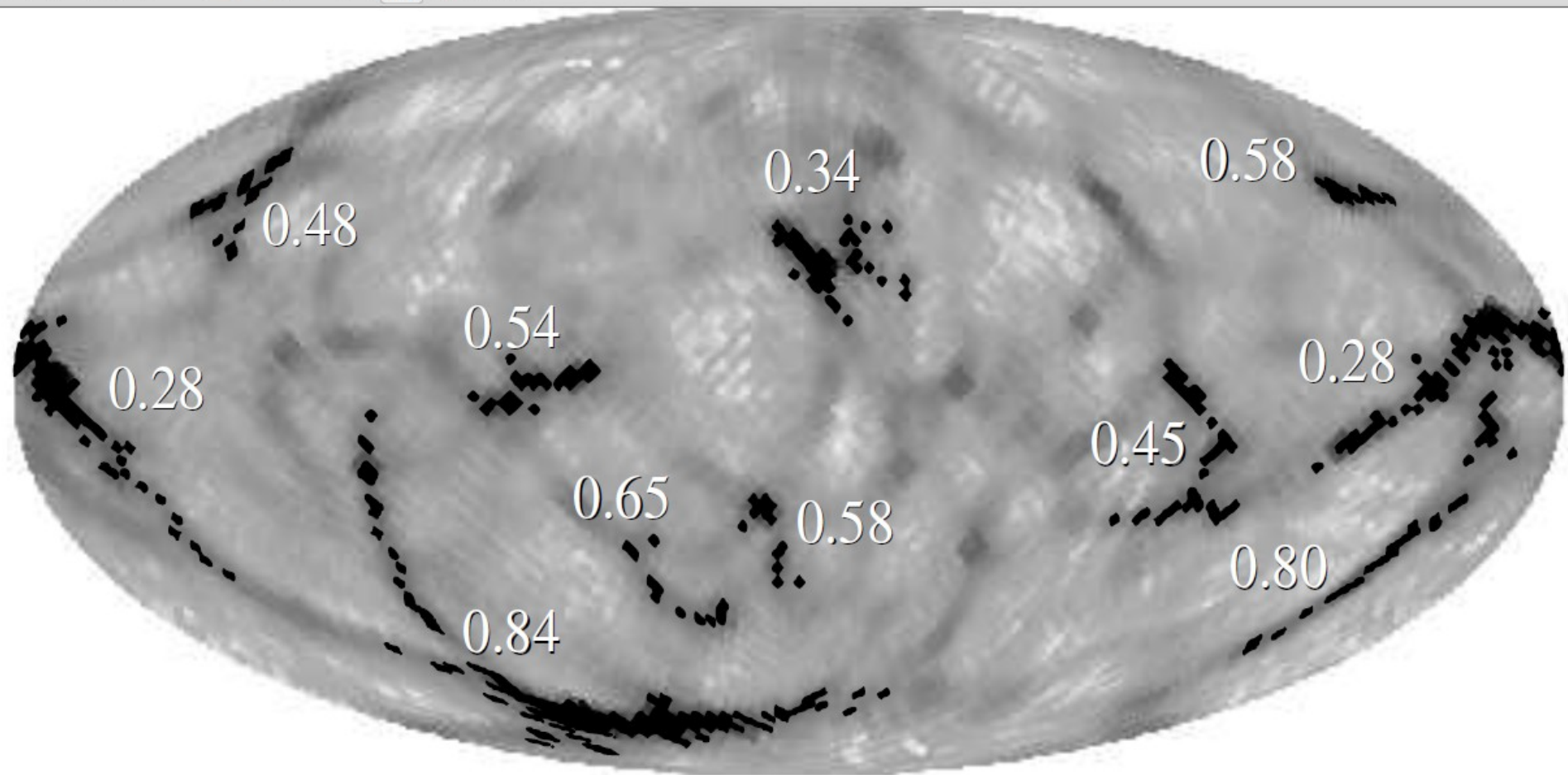
Voids with a surrounding overdense shell exhibit a rising cumulative density profile, which overcompensates the underdensity and therefore reach positive values between 2 and 3 times the void radius. These voids, dubbed S--type after its shell--like structure, are likely collapsing

Voids with a smoothly rising integrated density profile that approaches the mean density at large distances (hereafter R--type voids) show a continuous expansion.

(Ceccarelli et al., 2018)



## Structure of a void shell



(Ruiz et al., 2015)





Spiral galaxy MCG+01-02-015 located in the center of a void (ESA/HUBBLE & NASA AND N. GORIN (STSCI))

## SUMMARY

LSS is a connected net  
of filaments, walls,  
knots and voids

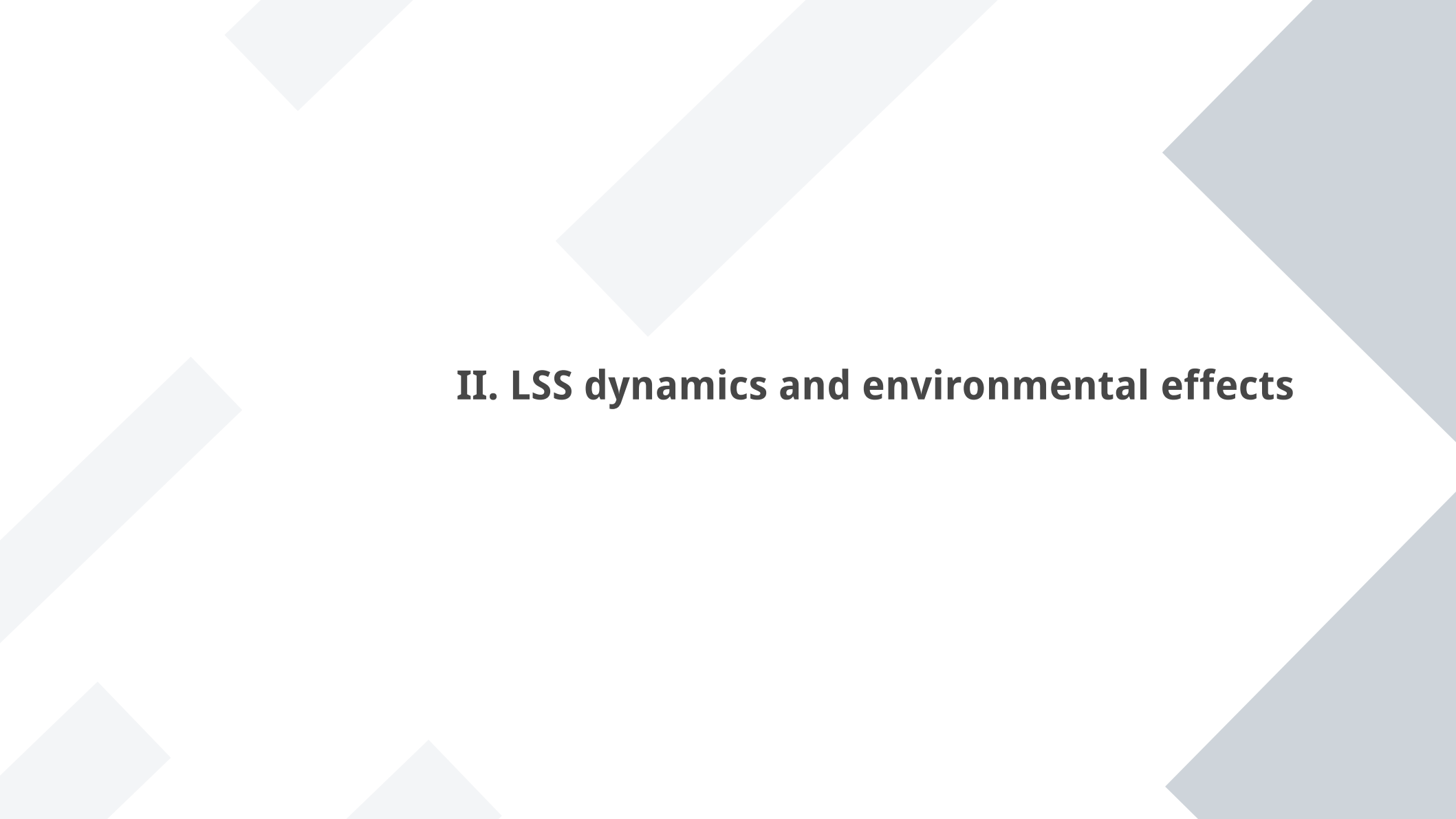
The structures are  
constantly evolving

The identification of  
the component of the  
LSS is not a simple  
procedure

The local universe can  
be accurately mapped  
with distances that are  
not redshift dependent

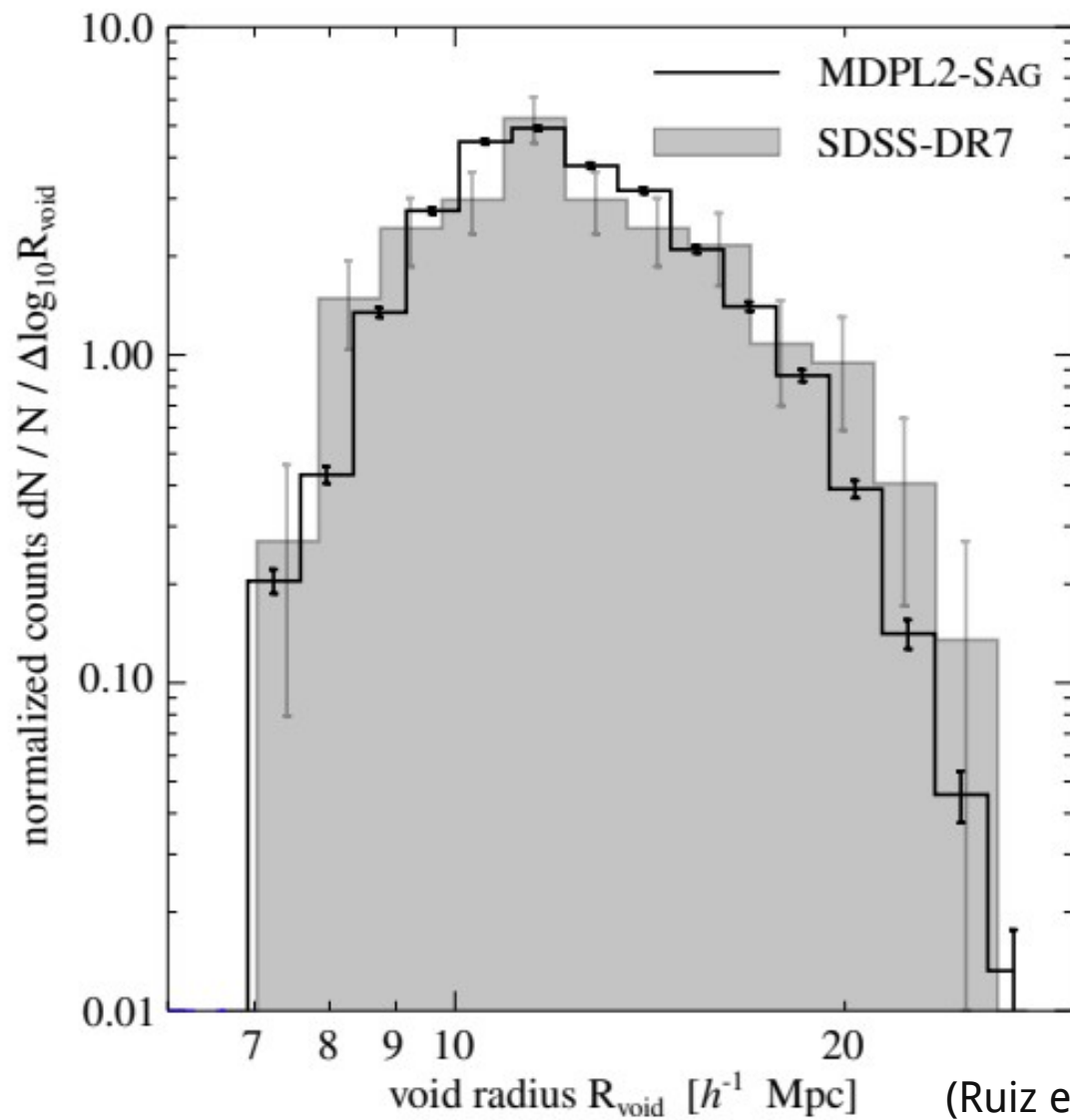
For LSS analysis it is  
necessary to use both  
simulation and  
observational data

LSS at larger distances  
is analysed statistically



## **II. LSS dynamics and environmental effects**





(Ruiz et al., 2018)

## Review

The superstructures, or FVS, are the largest overdense regions; gravitationally bound systems that will evolve to become virialized structures

FVS are non-symmetrical and have very diverse shapes/complex topology

FVS can be as large as 150 Mpc/h but does not cover a significant volume fraction

Voids are defined as the largest spherical volume within which the matter density is below of less than 10% of the mean density

Voids are the dominant part of the volume of the LSS

There are two void types: R—type voids show density profiles that smoothly approaches to the mean density, while S—type voids have overdense shells surrounding them

## Review

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***Are FVS and voids randomly distributed? Does voids tend to be located far away from FVS?***

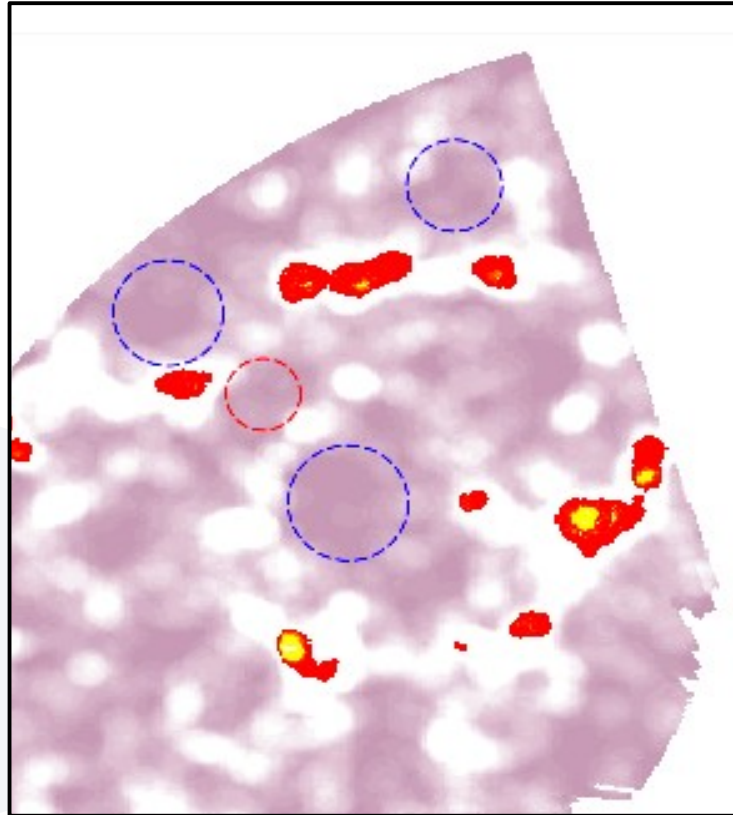
**The 2—point correlation function characterizes the distribution of any set of **points****

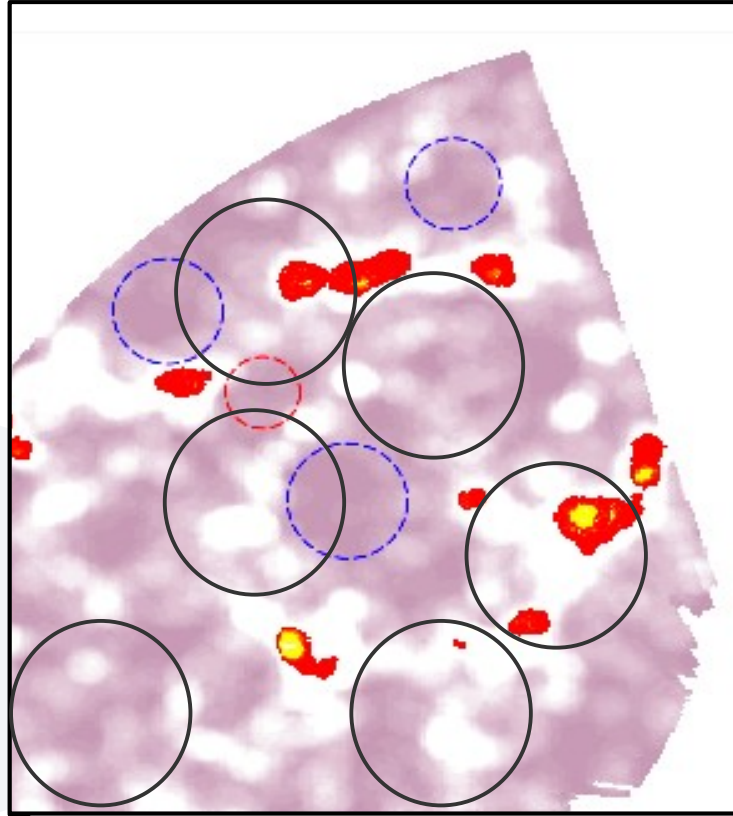
----→ the formalism is based on the computation of probabilities

2—point cross—correlation function quantifies the relative distributions of two types of points, defined as the excess probability of finding a pair of objects at a given separation compared to the expected from a random distribution

Using the radii of random spheres as indicators of the scale, it is possible to compute probabilities for extended structures







$$P(\text{void} \cap \text{FVS}) \simeq \frac{N_{\text{void} \cap \text{FVS}}}{N_T},$$

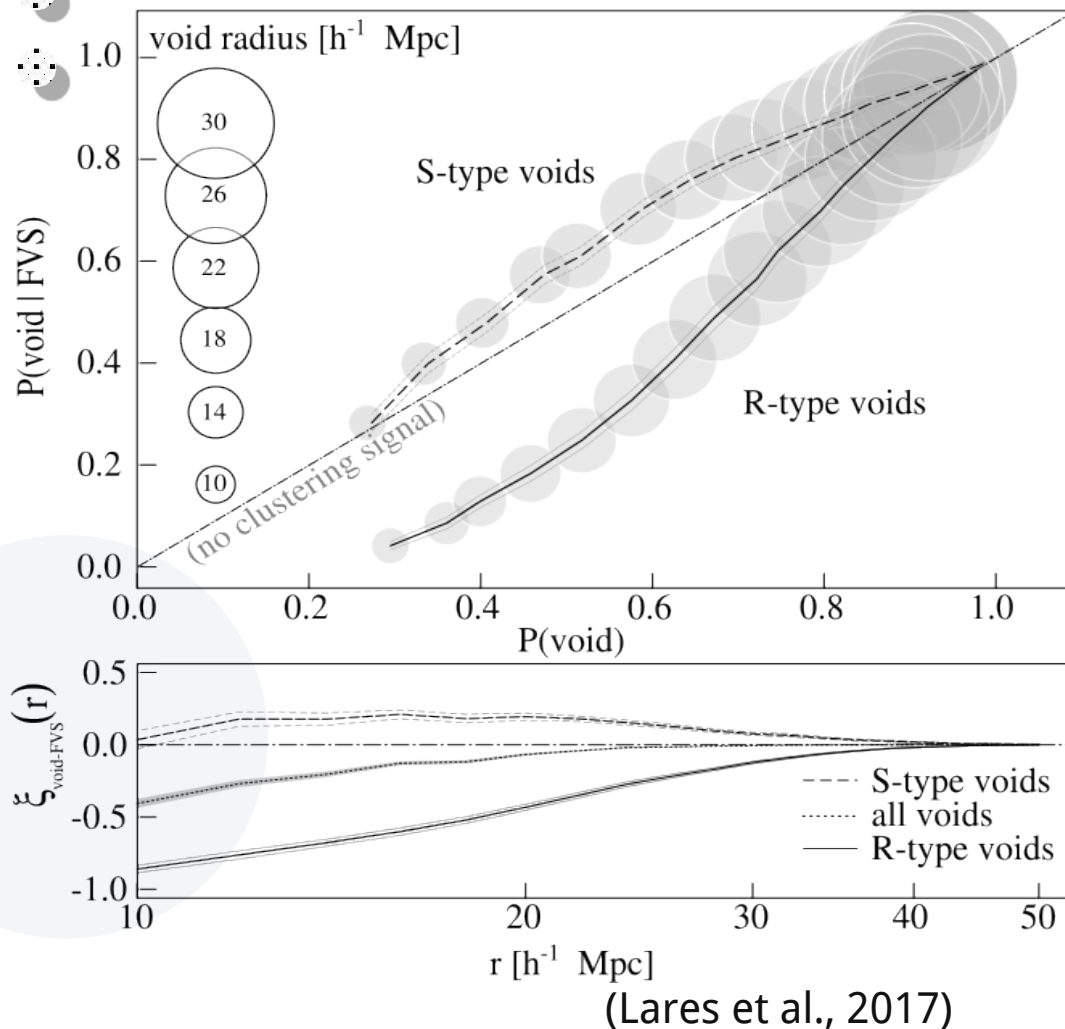
and similarly,

$$P(\text{void}) \simeq \frac{N_{\text{void}}}{N_T},$$

$$P(\text{FVS}) \simeq \frac{N_{\text{FVS}}}{N_T},$$

$$P(\text{void} \cap \text{FVS}) \simeq P(\text{void} | \text{FVS}) P(\text{FVS})$$

$$P(\text{void} | \text{FVS}) = P(\text{void}) (1 + \xi_{\text{void-FVS}}(r)),$$

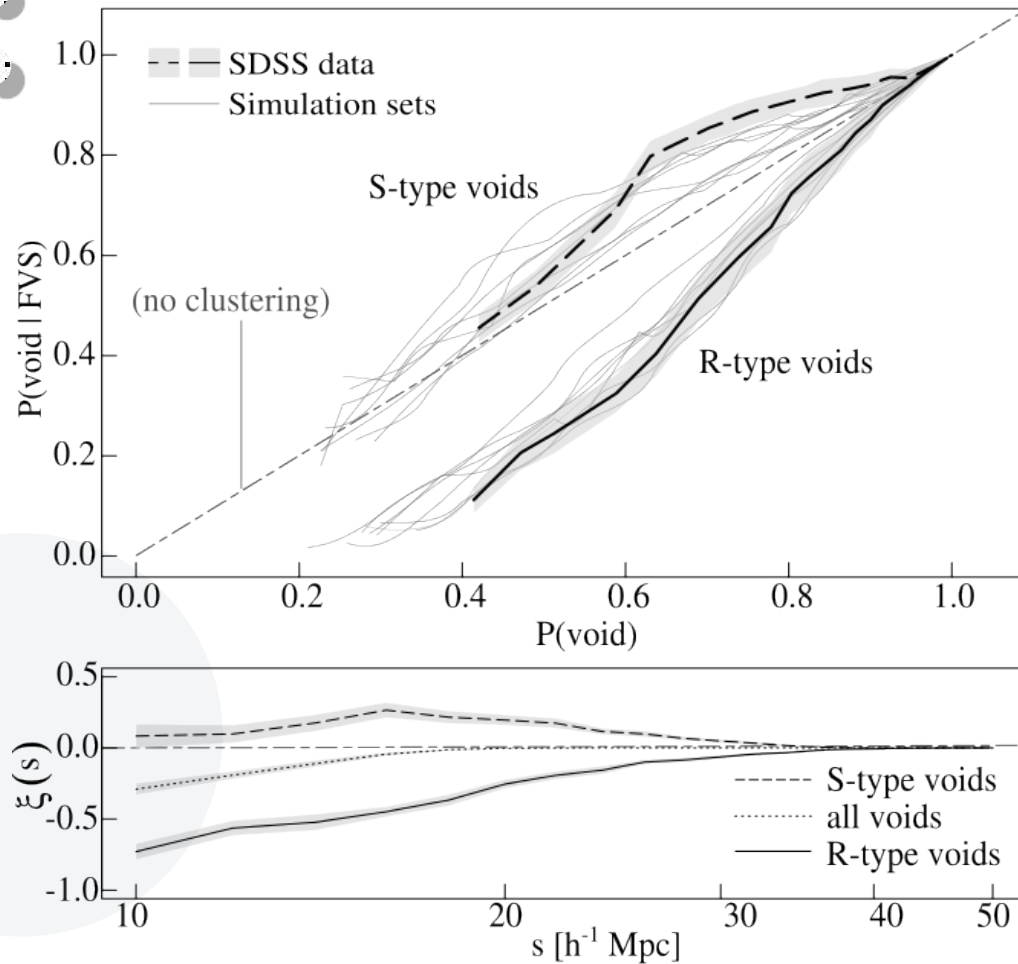


if a random sphere contains a FVS, the probability of containing also an S-type void is higher than what should be expected for a random distribution of voids (represented by the dot-dashed line)

Conversely, the probability that a FVS and an R-type void are in contact with the same random sphere is smaller in the full range of sphere radii, indicating that R-type voids tend to avoid FVSs.

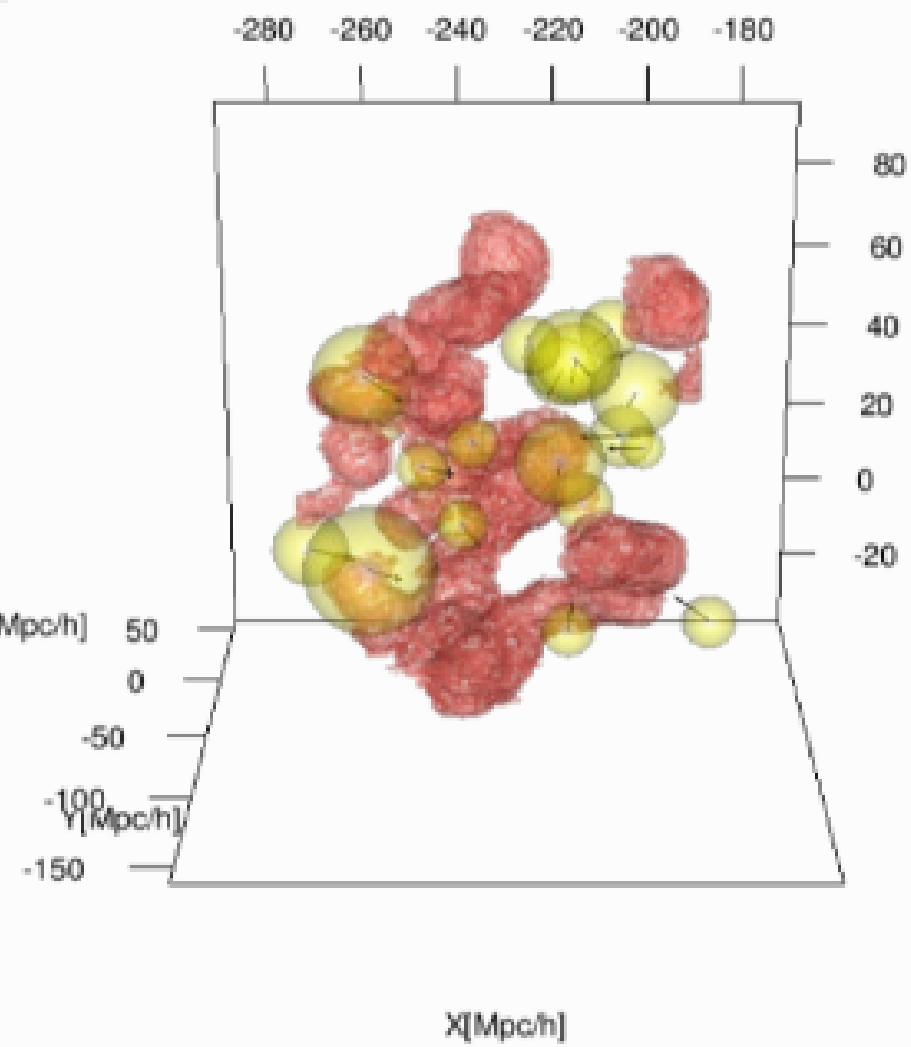
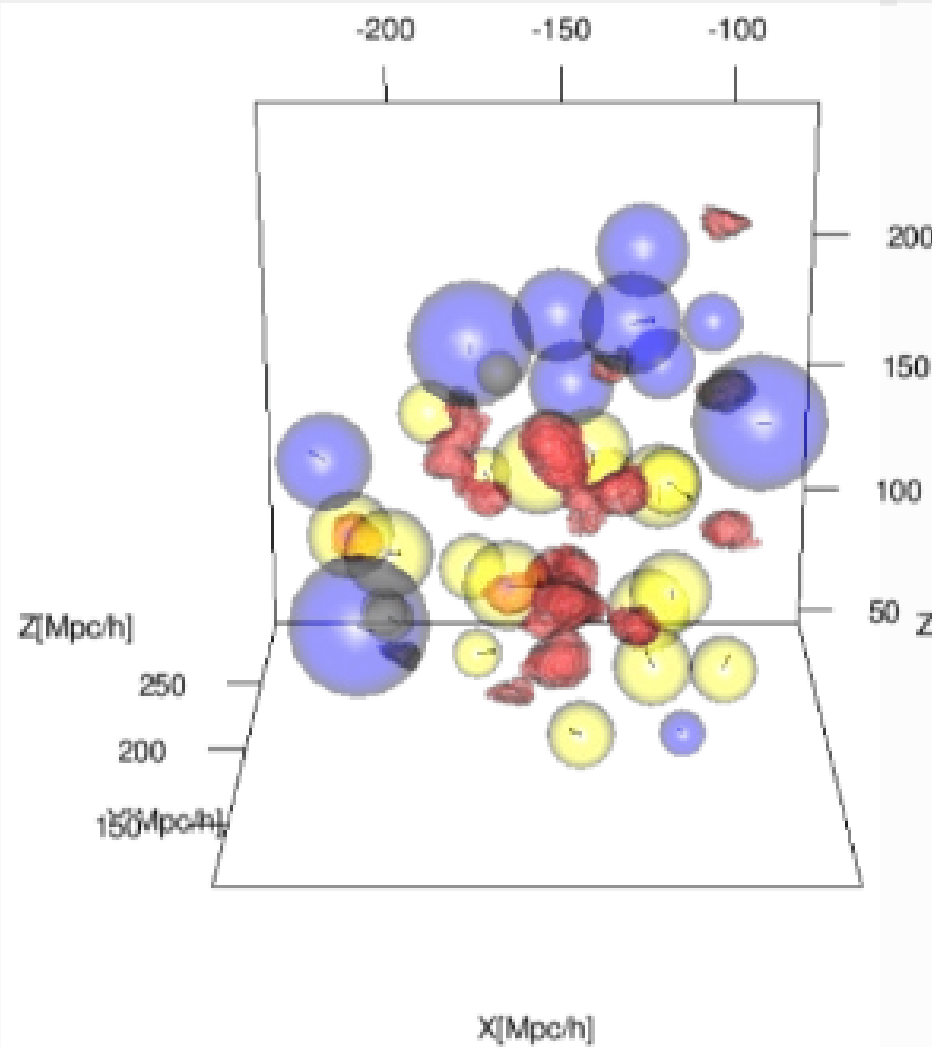
As the sizes of the spheres grow, the probability tends to show no clustering signal since any random sphere is likely to contain a FVS due to their large volume

From a scale of approximately  $40 h^{-1}$  Mpc, no significant correlation signal can be detected.

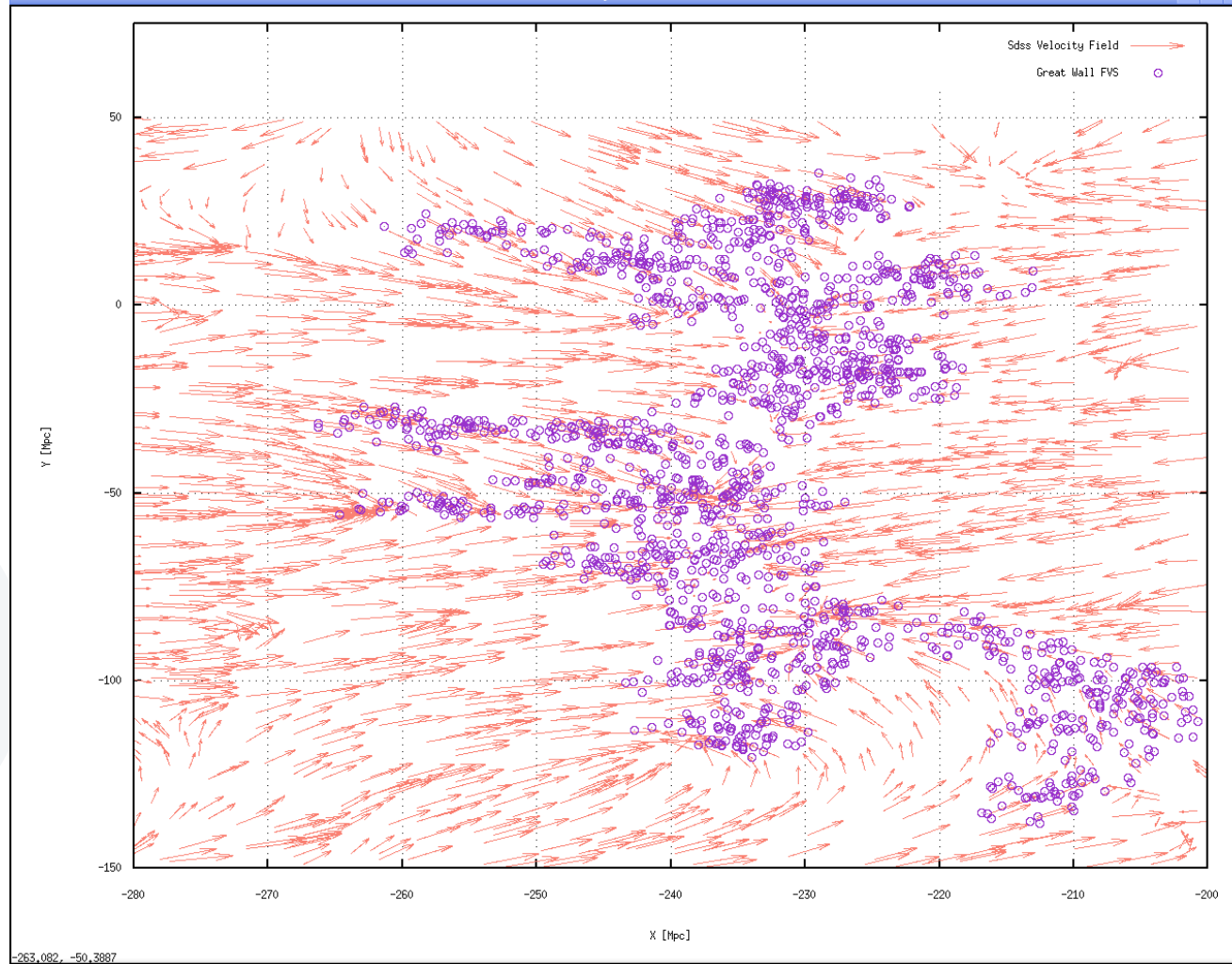


(Lares et al., 2017)

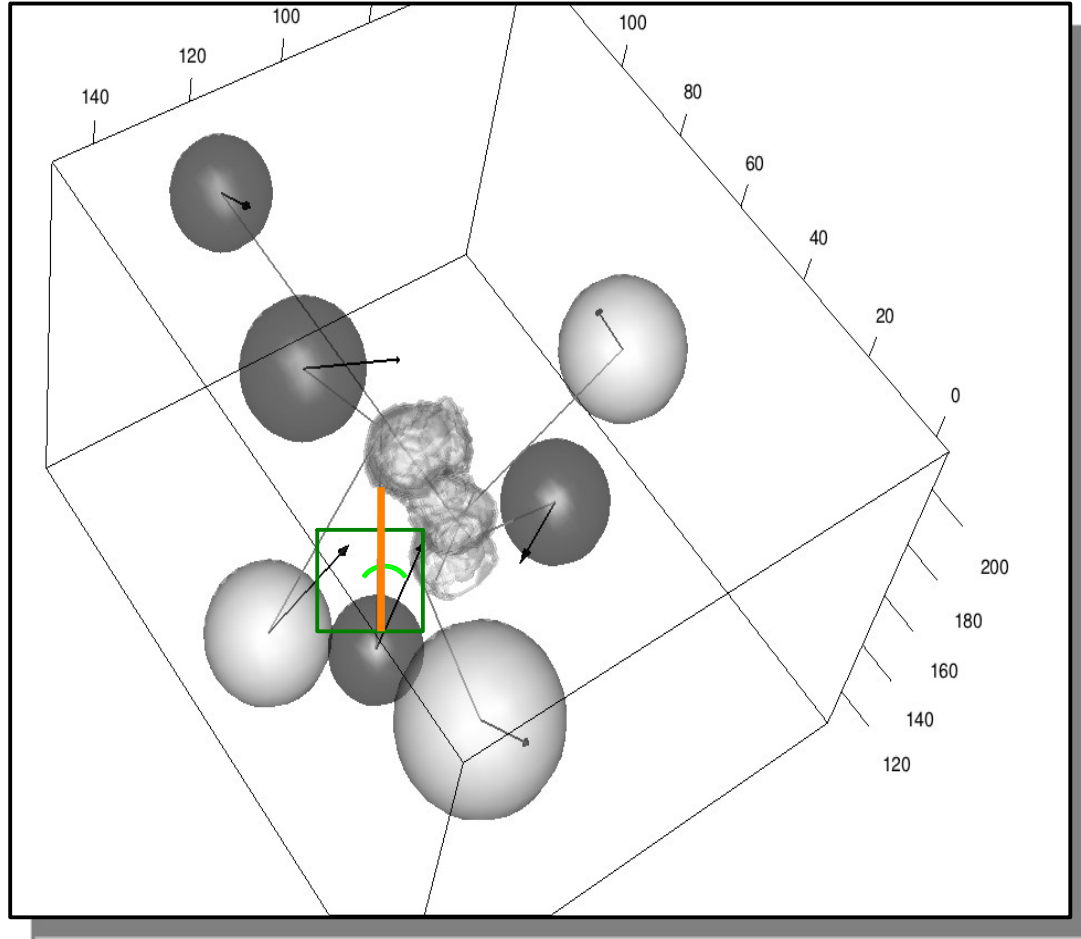




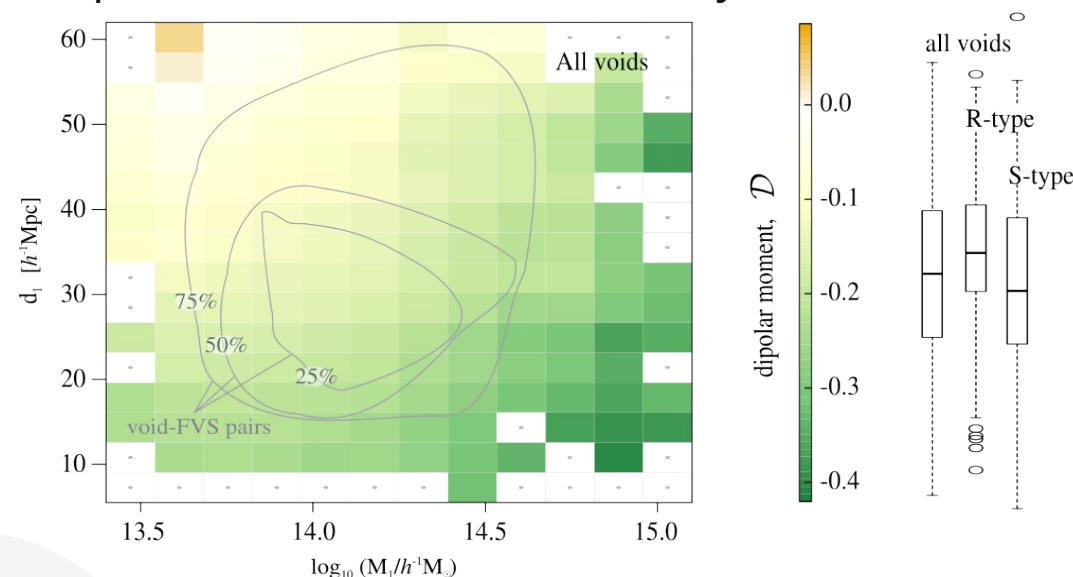
## SDSS Great Wall galaxies + lineal velocity field from Wang et al. (2010)



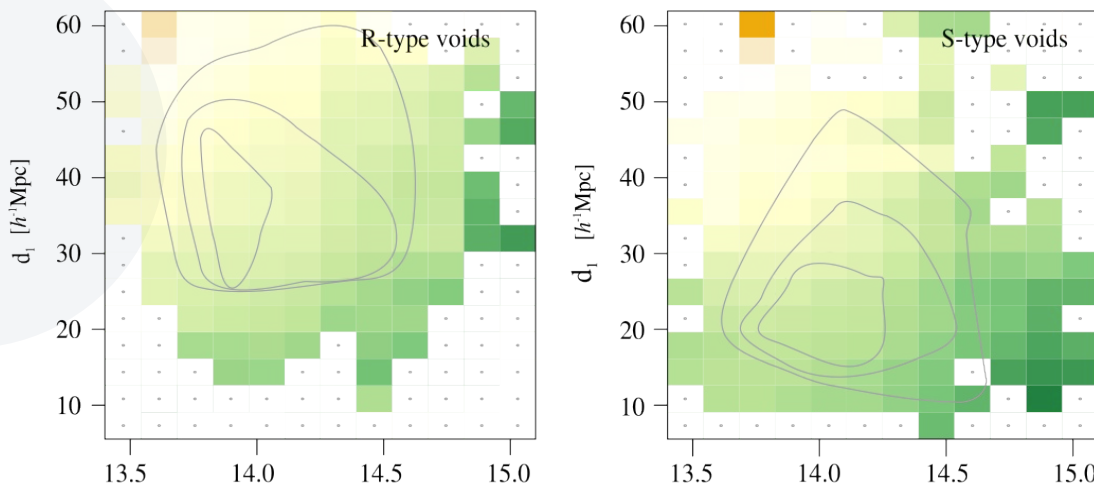
The relative movement of voids respect to the FVS can be analysed by the calculation of the projected void velocity in the direction of the core of the nearest FVS



## Dipolar moment of the void velocity as a function of distance and mass of the nearest FVS



The higher negative values of the dipole (that indicates an infall signal for the pairs) occurs mainly when the voids are located close to a FVS and this excess is significant even at distances as large as 50 Mpc/h



There is a stronger infall signal for S-type voids, which is noticeable up to nearly 25 Mpc/h

(Lares et al., 2017)



## SUMMARY

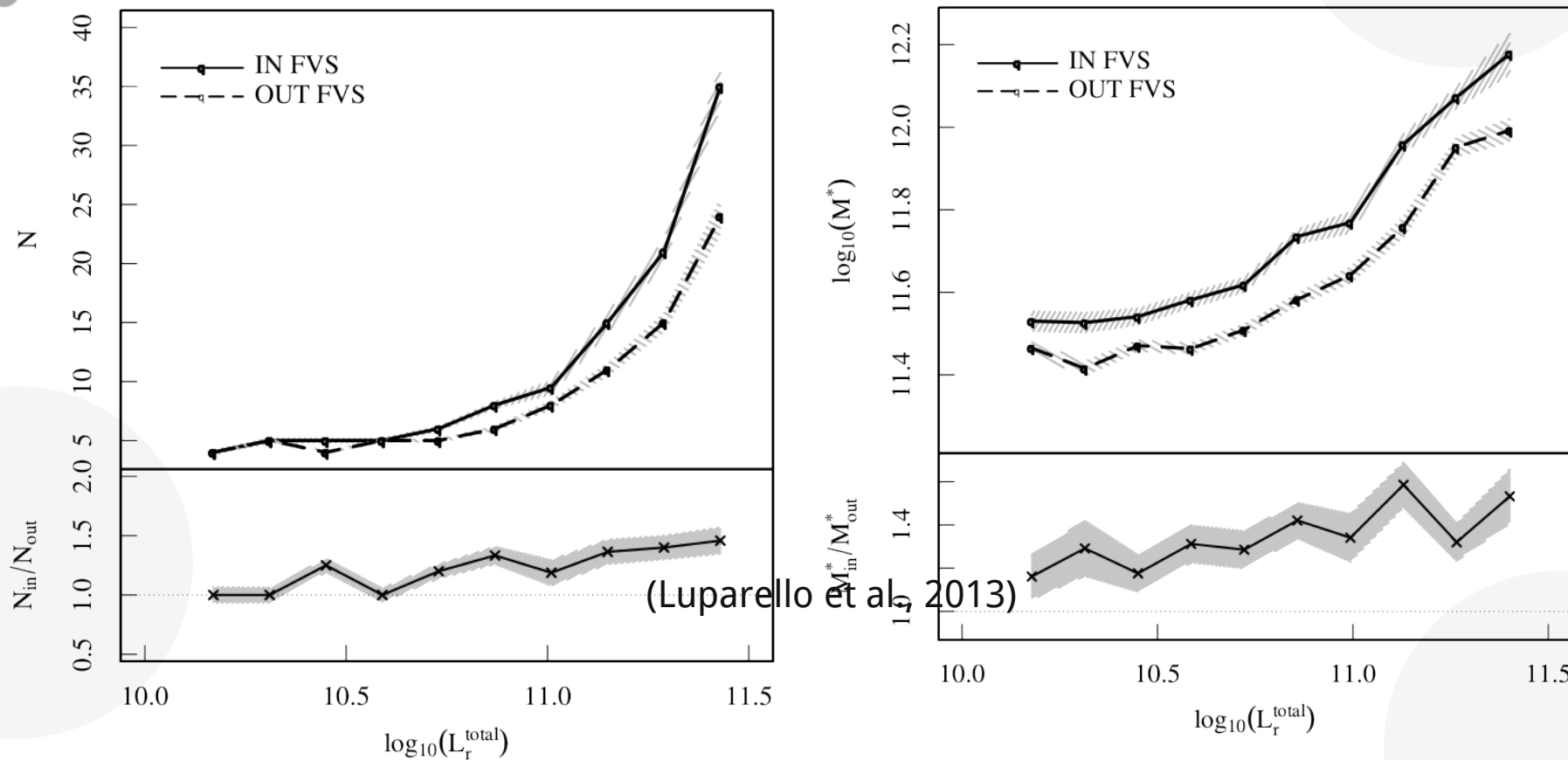
The dynamics and spatial distribution of voids are tightly related to the superstructures

S-type voids show a clear clustering and infalling pattern onto the FVSs.

R-type voids tend to be located in zones not populated by FVSs

R-type voids are going away from FVSs

# Properties of galaxies and groups inhabiting extreme LSS environments



Multiplicity and stellar mass content of galaxy groups as a function of their luminosity (a mass proxy)

## Properties of galaxies and groups inhabiting extreme LSS environments

Galaxy groups located in FVS present a 1.3 larger content of stellar mass respective to same luminosity groups inhabiting less dense environments (Luparello et al., 2013)

The mean velocity dispersion of group galaxies is 35% higher than the one for groups of the same luminosity not located in FVS (Luparello et al., 2013)

The “age” of the groups in FVS is defined from their current SFR, showing that groups in FVS are older than same luminosity groups elsewhere (Luparello et al., 2015)

The FVS influence over the BGGs can be found in their color, SFR, stellar mass content and age, and also depends on the morphological type of the BGG: Late—type BGGs are brighter, 0.11 redder, with an excess of 10% of stellar mass and 30% older when they populate groups in FVS (Luparello et al., 2015)

## Properties of galaxies and groups inhabiting extreme LSS environments

Galaxies that inhabit haloes of a given mass are bluer, have a higher star formation rate and are less concentrated when the host halo is inside voids compared to other regions (Rodriguez-Medrano et al., 2022)

Also, galaxies in R-type voids are bluer, with higher SFR and less concentration than in S-type voids (Rodriguez-Medrano et al., 2022)

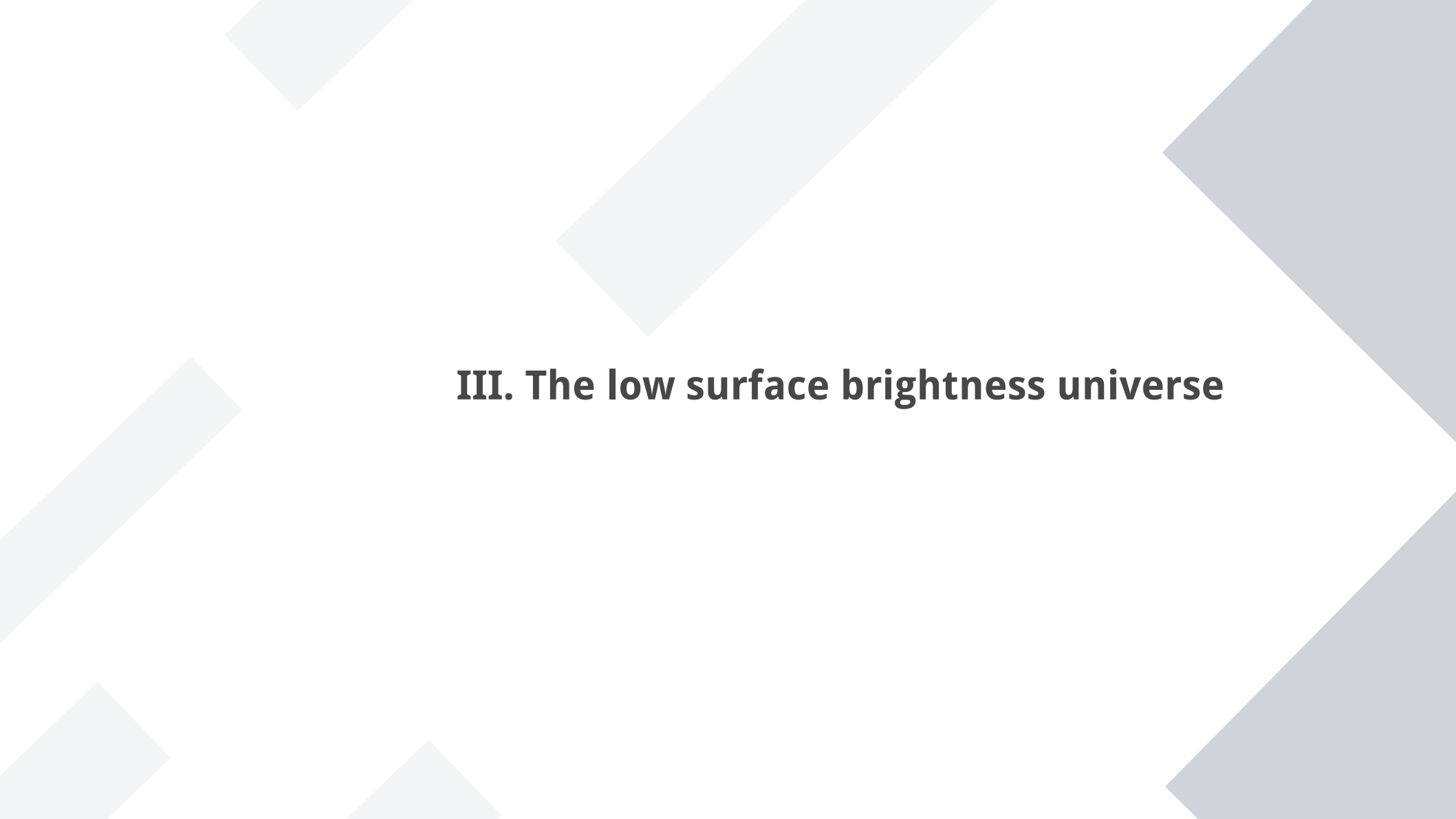
Inside voids, there is a strong decrease in HOD concerning the Field results: the mean number of satellites fall to 50% (Alfaro et al., 2022)

Inside FVS, the HOD shows a significant increase respect to the Field, with a 40% excess in the mean number of satellites (Alfaro et al., 2022)



## **“OPEN” QUESTION**

Can these signals be considered as indicators of second—order assembly bias?



### **III. The low surface brightness universe**

## Low surface brightness galaxies (LSBGs)

Low-surface-brightness galaxies are conventionally defined as galaxies with central surface brightnesses ( $\mu$ ) fainter than the night sky (i. e.  $\mu \approx > 23 \text{ mag/arcsec}^2$ )

LGBs comprises a wide range of size and masses

It is proposed that LSBGs evolves more slowly than normal galaxies, and still in an early formation stage

They contain more gas than normal galaxies but at lower densities

Since massive stars are the sources of heavy elements, LSBGs have much lower metallicities than normal galaxies

Their discovery prompted to revise statistics on galaxy types and numbers, and it is now believed that low surface brightness galaxies may account for up to 50% of the total population of galaxies



(surface brightness (SB) quantifies the apparent brightness or flux density per unit angular area of a spatially extended object)

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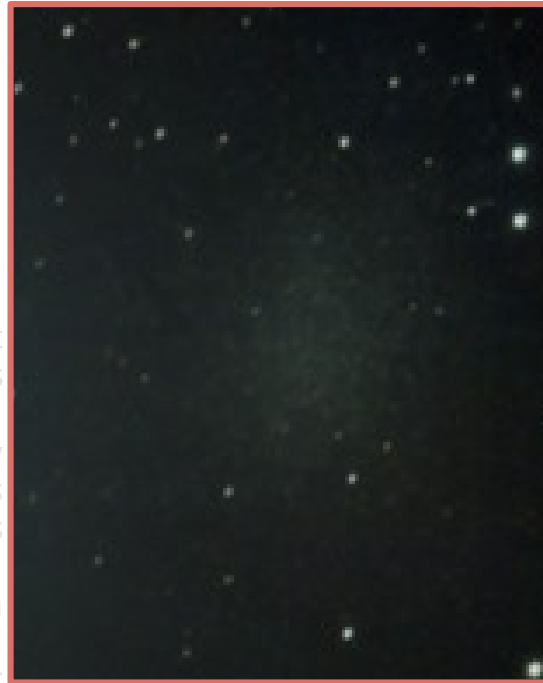
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© Anglo-Australian Observatory

*LSBG Leo I (AAO/David Malin)*

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**Measures suggest that LSBGs have over 95% of their mass as non-baryonic dark matter**

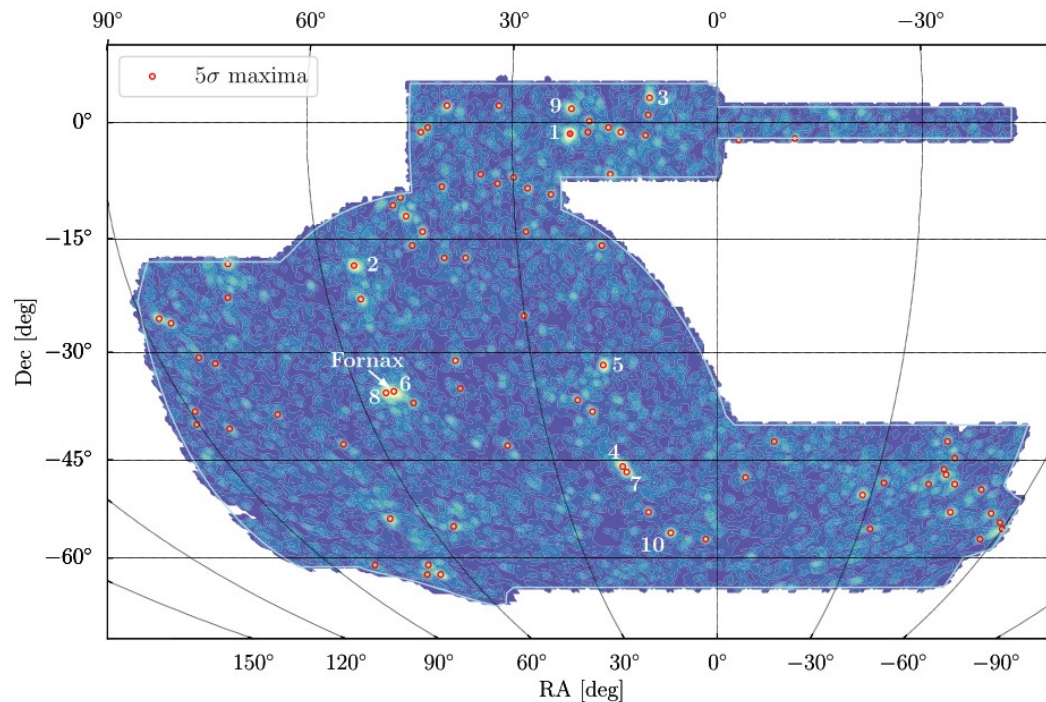
# LSBG catalogue from Dark Energy Survey (DES)

Tanoglidis et al. (2020)

DES is an optical–near infrared imaging survey covering  $\sim 5000 \text{ deg}^2$  of the southern Galactic cap using the Dark Energy Camera (DECam; Flaugher et al. 2015)

The largest catalogue of LSBGs to date, providing 23,790 galaxies with extinction-corrected mean effective surface brightnesses  $\mu_{\text{eff}}(g) > 24.2 \text{ mag arcsec}^{-2}$ .

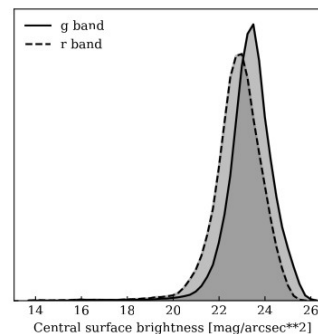
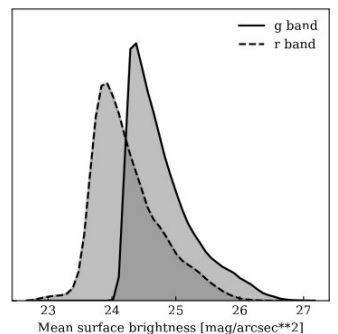
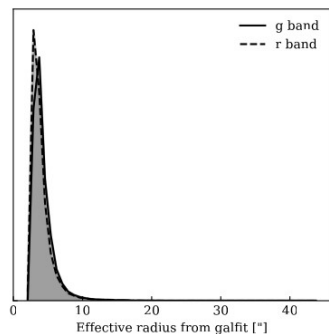
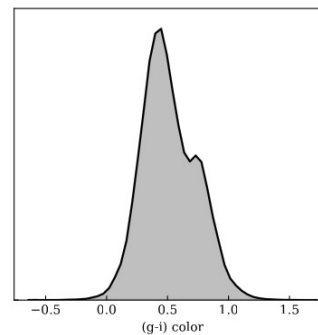
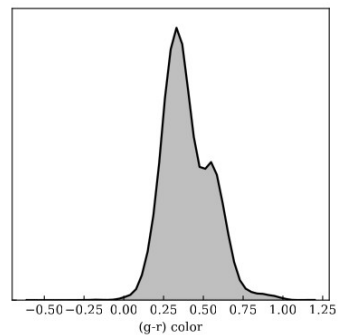
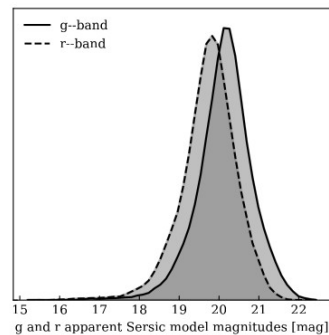
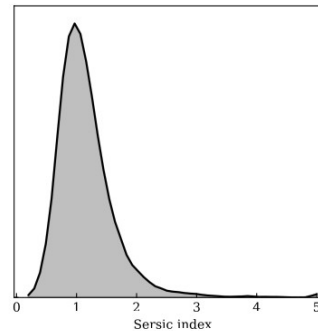
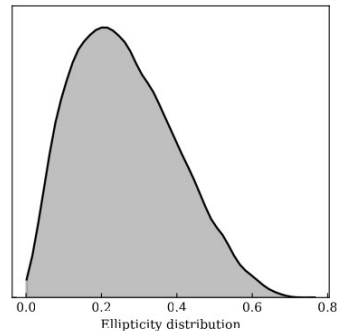
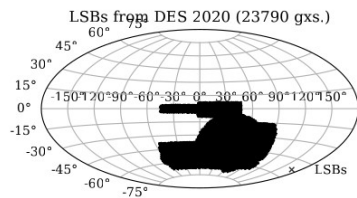
Unfortunately, there is no redshift estimation for DES galaxies



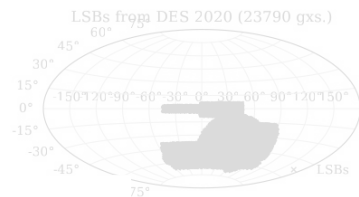


# Distribution of main LSBGs properties from DES

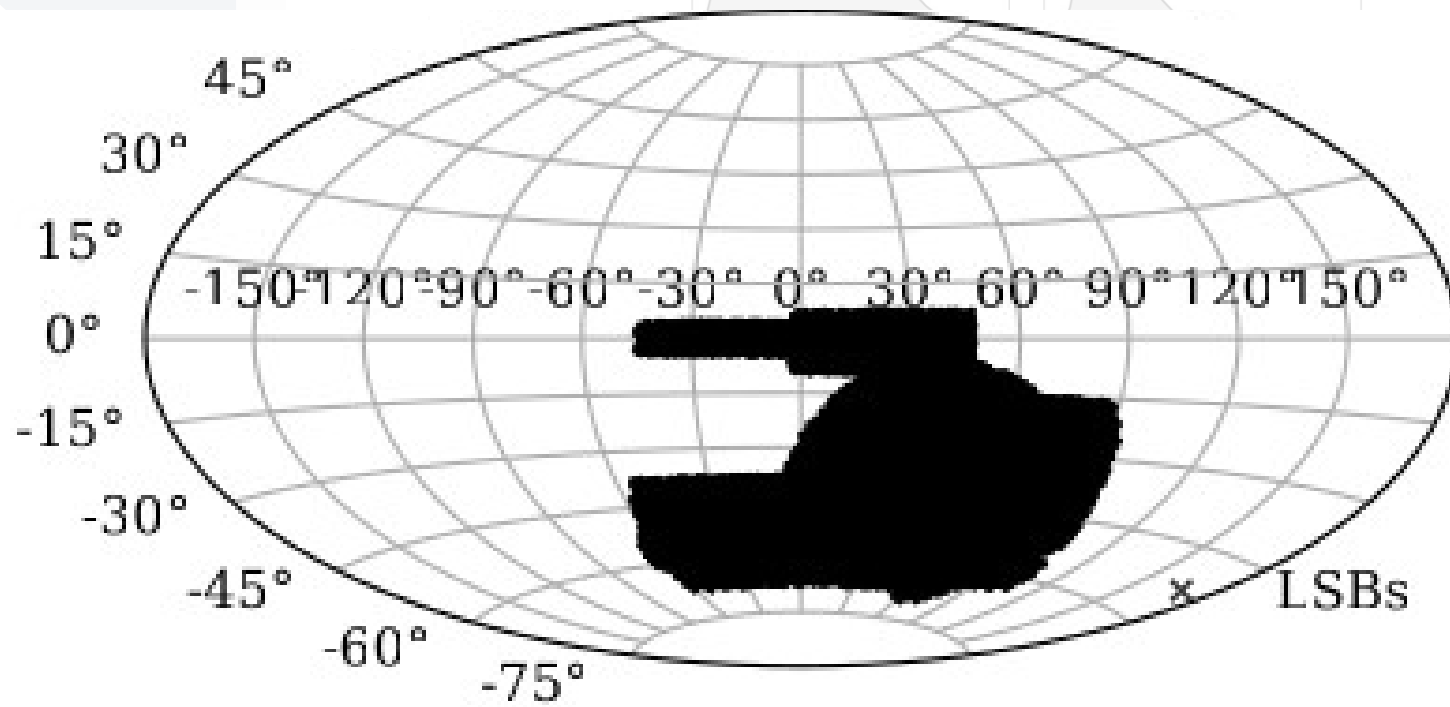
*LSS traced by LSBGs*

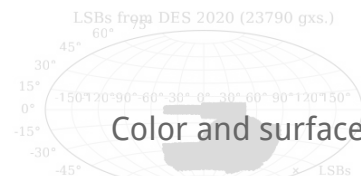




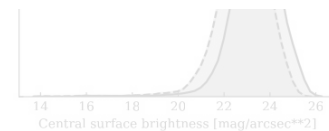
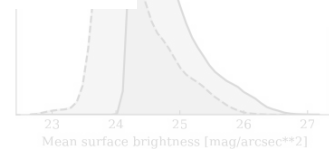
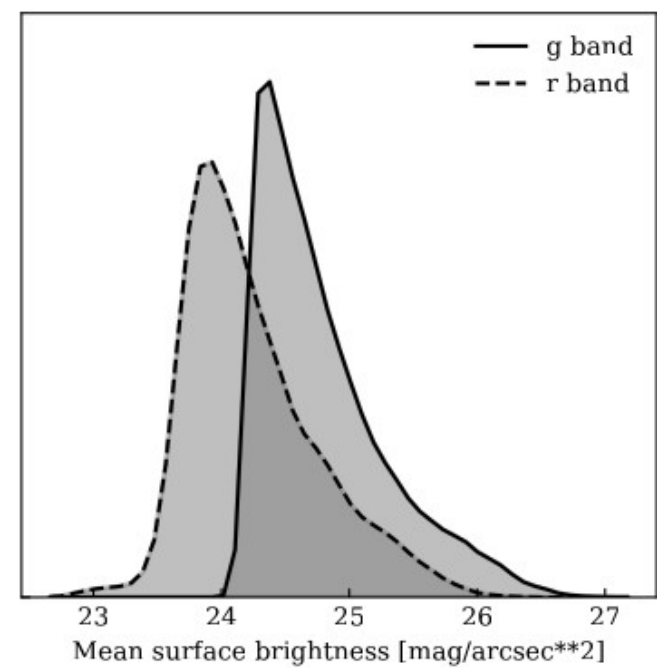
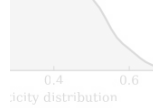
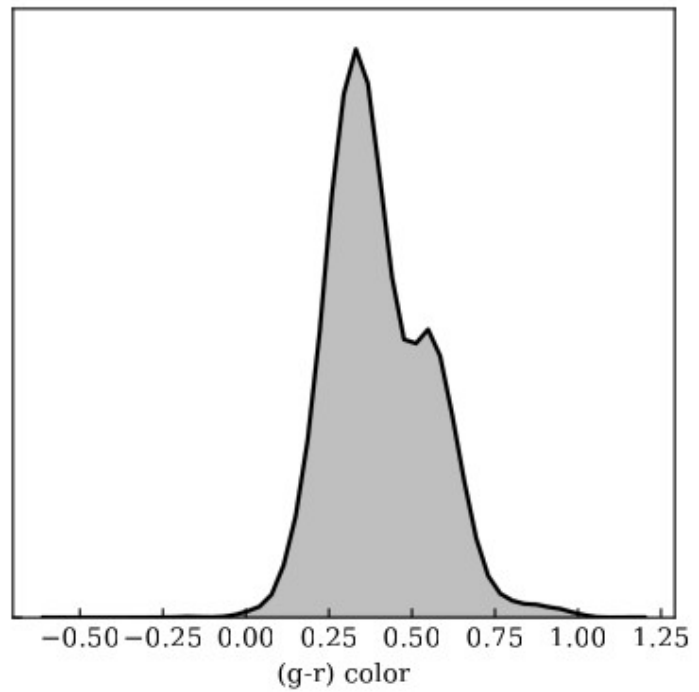


DES footprint



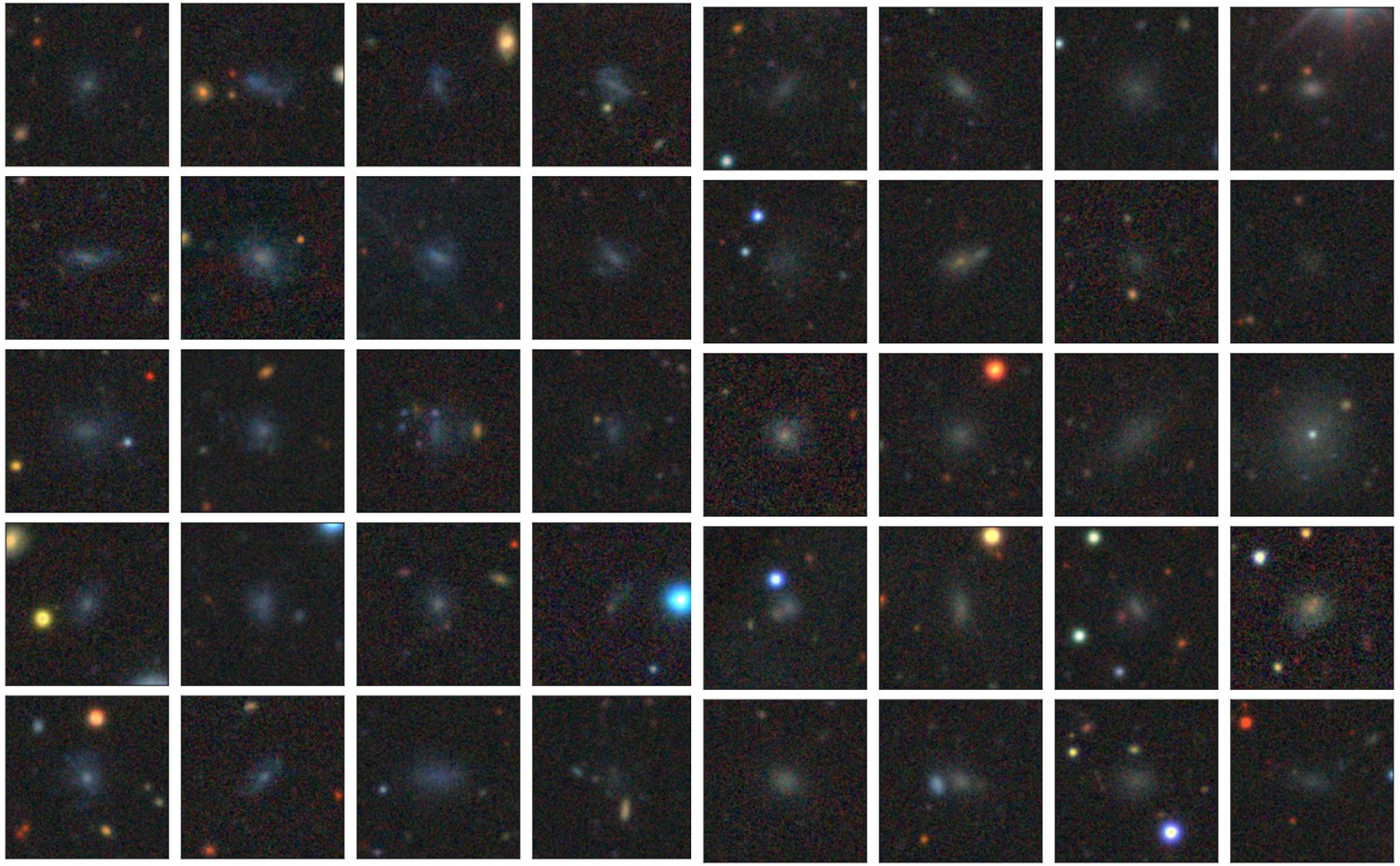


Color and surface brightness distribution of LSBGs from DES

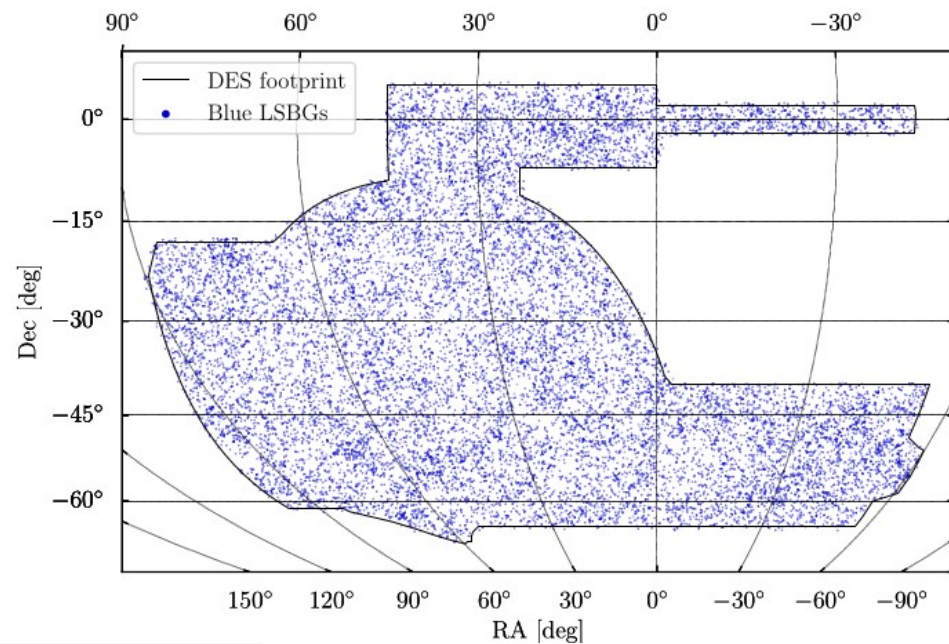


Blue LSBGs

Red LSBGs

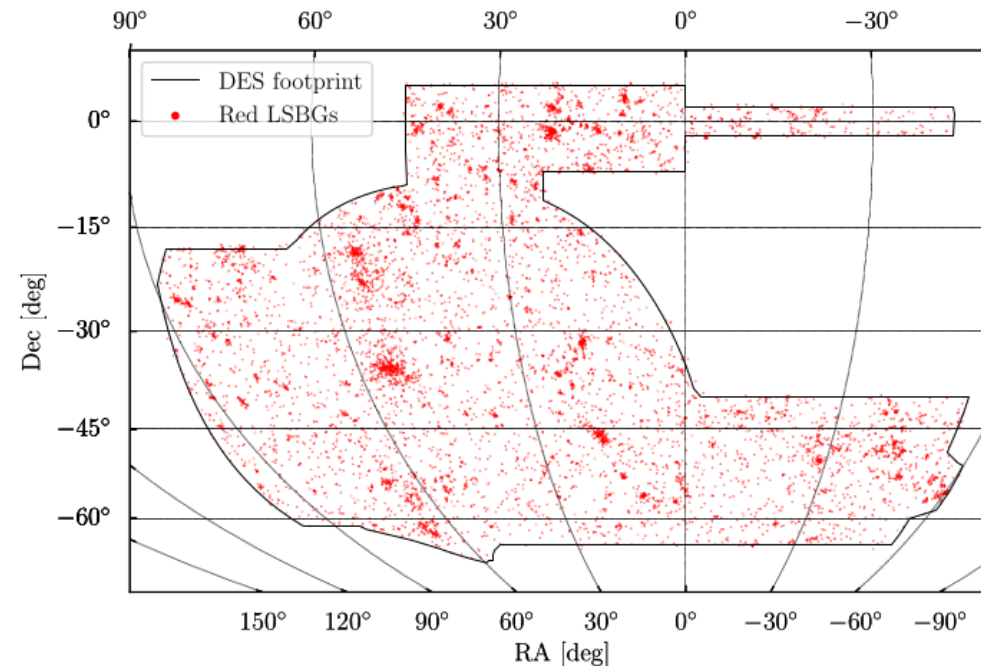


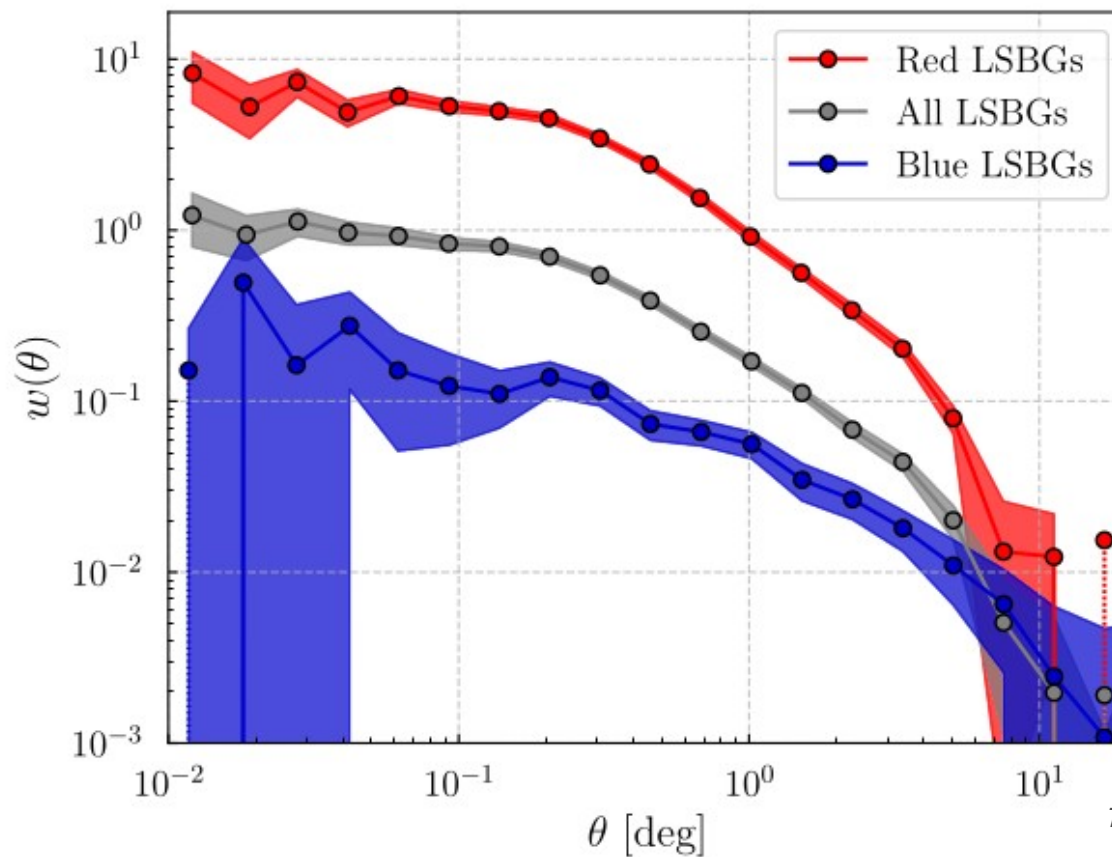




*Tanoglidis et al. (2020)*

LSBGs angular distribution in the footprint of the Dark Energy Survey (DES)



Projected correlation function  $w(\theta)$  for LSBGs from the Dark Energy Survey (DES)

Tanoglidis et al. (2020)



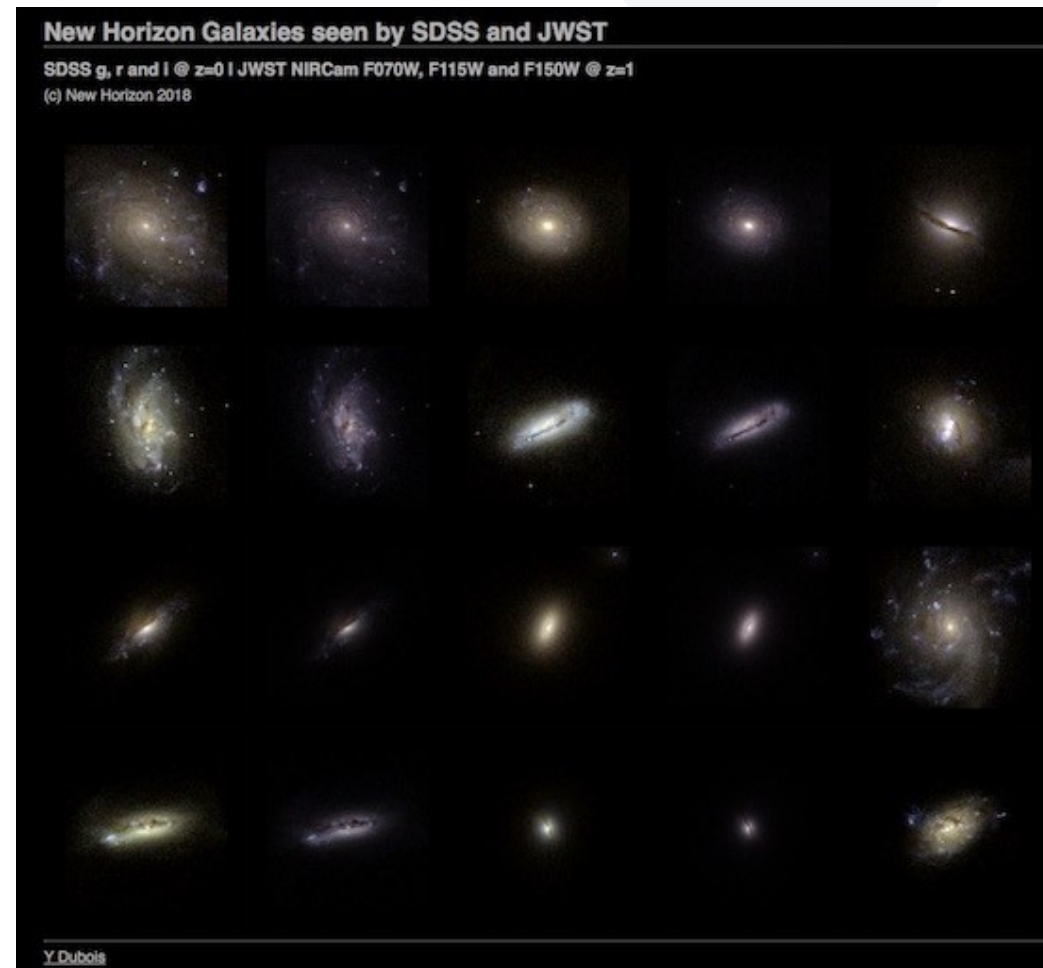
## NewHorizon simulation (Dubois et al. 2020)

NewHorizon cosmological, hydro-dynamical simulation is a high-resolution zoom of a region within the Horizon-AGN simulation (Dubois et al. 2014b; Kaviraj et al. 2017)

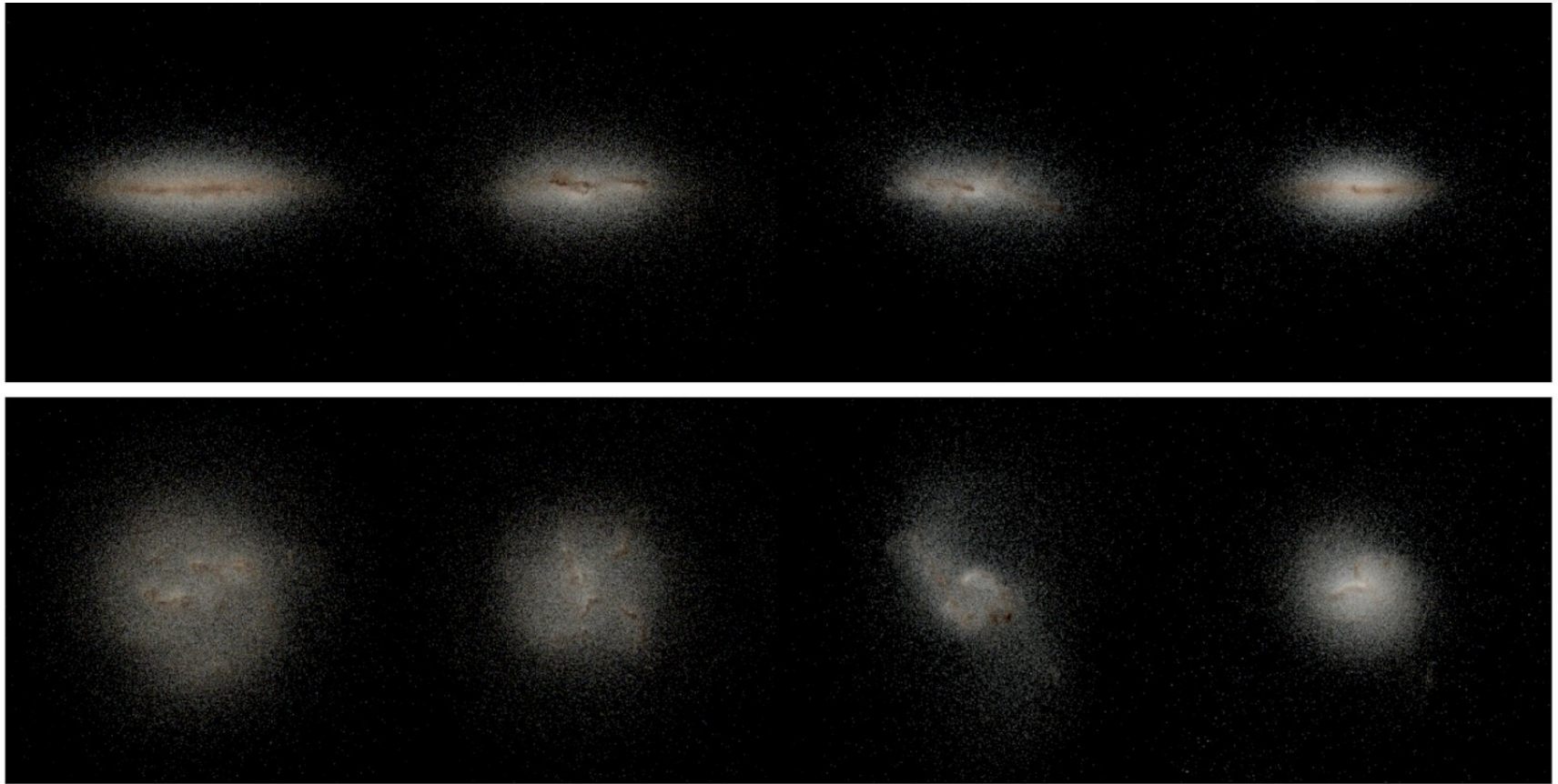
It employs the adaptive mesh refinement code RAMSES (Teyssier 2002)

The high-resolution zoom has a volume of  $\sim(16 \text{ Mpc})^3$

Given that the zoom region used to create NewHorizon has an average density, this simulation does not contain high-density environments like clusters.



Examples of simulated LSBGs from NewHorizon



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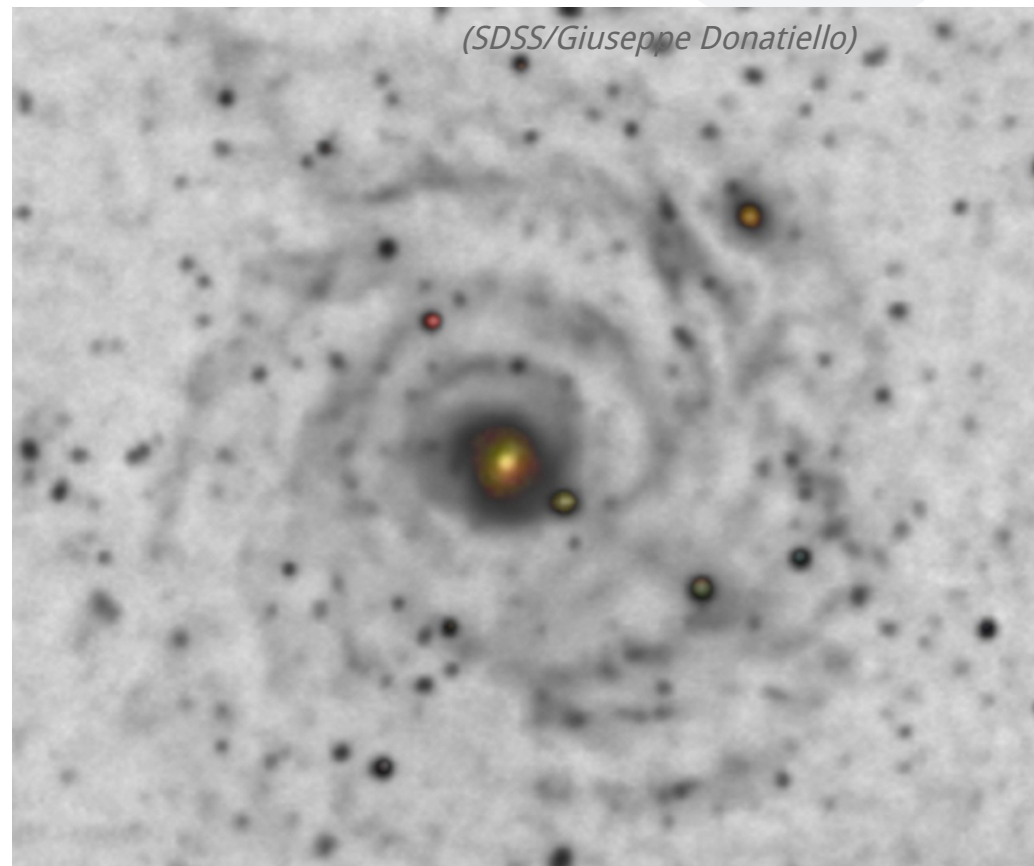


## Giant LSBGs

Malin 1 is a “extreme” example of a giant LSBG  
with 100 kpc radii and  $\mu = 28 \text{ mag/arcsec}^2$

Shows thick spiral arms and a massive disk

It is seven times larger than the Milky Way ( $\mu = 18 \text{ mag/arcsec}^2$ )



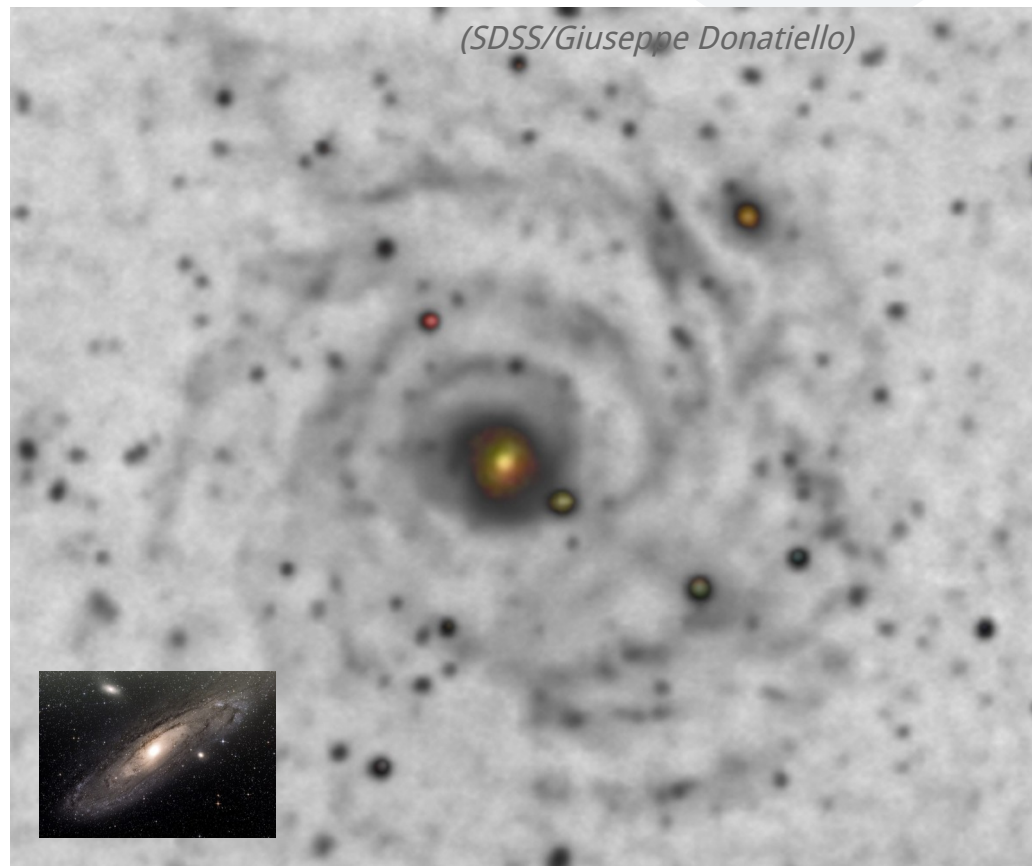


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# Selection of low and high surface brightness galaxies from Illustris TNG-300-1 simulation

TNG

PROJECT DESCRIPTION

PEOPLE + CONTACT

RESULTS

IMAGES + VIDEOS

DATA ACCESS

EXPLORE



Select a simulation to browse the available data files and get direct download links:

Show: ☒ Primary Volumes ☐ Subboxes

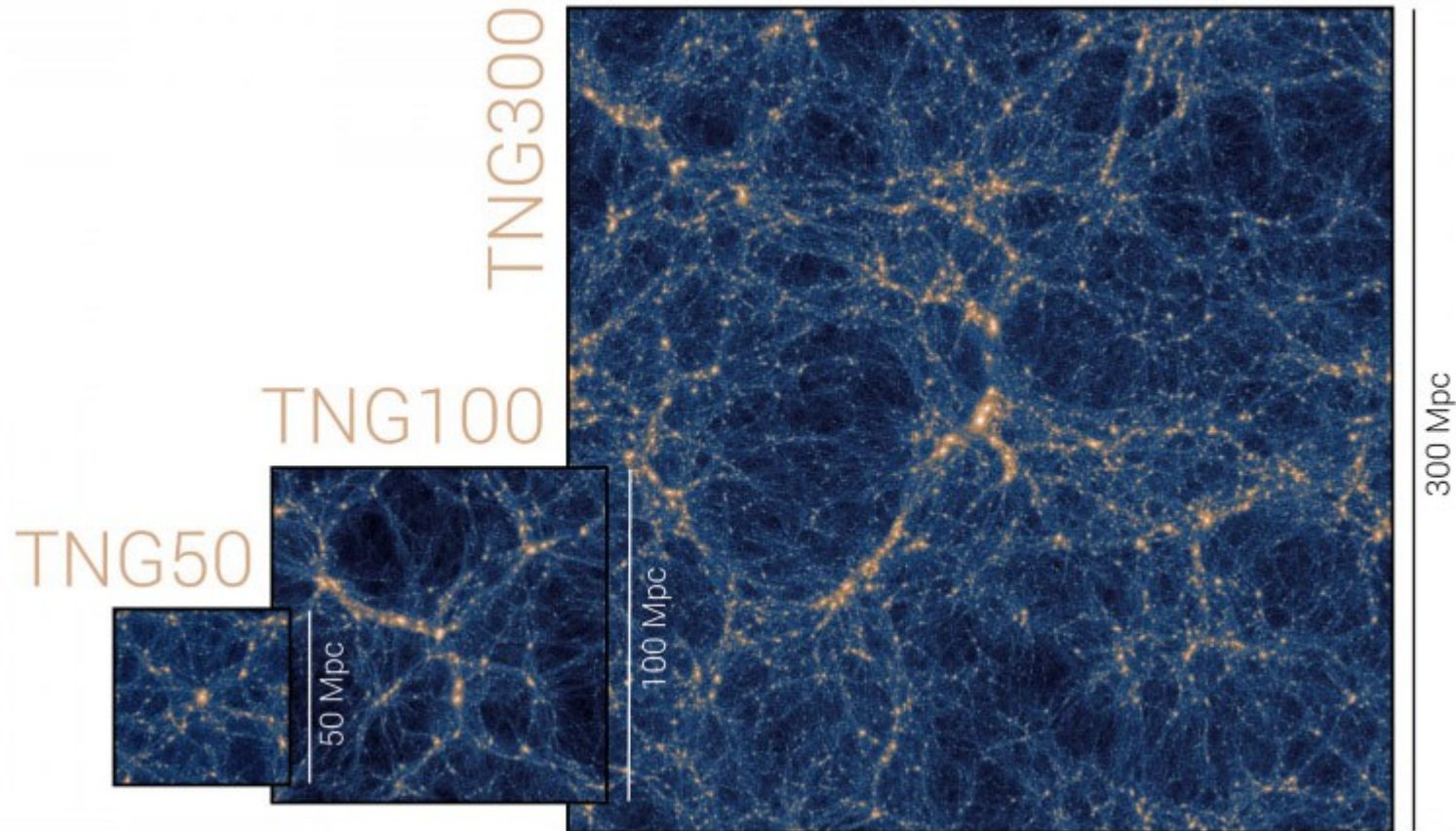
Simulation families: ☒ TNG ☒ Illustris

Types: ☒ Baryonic ☒ Gravity Only ☐ Low Resolution

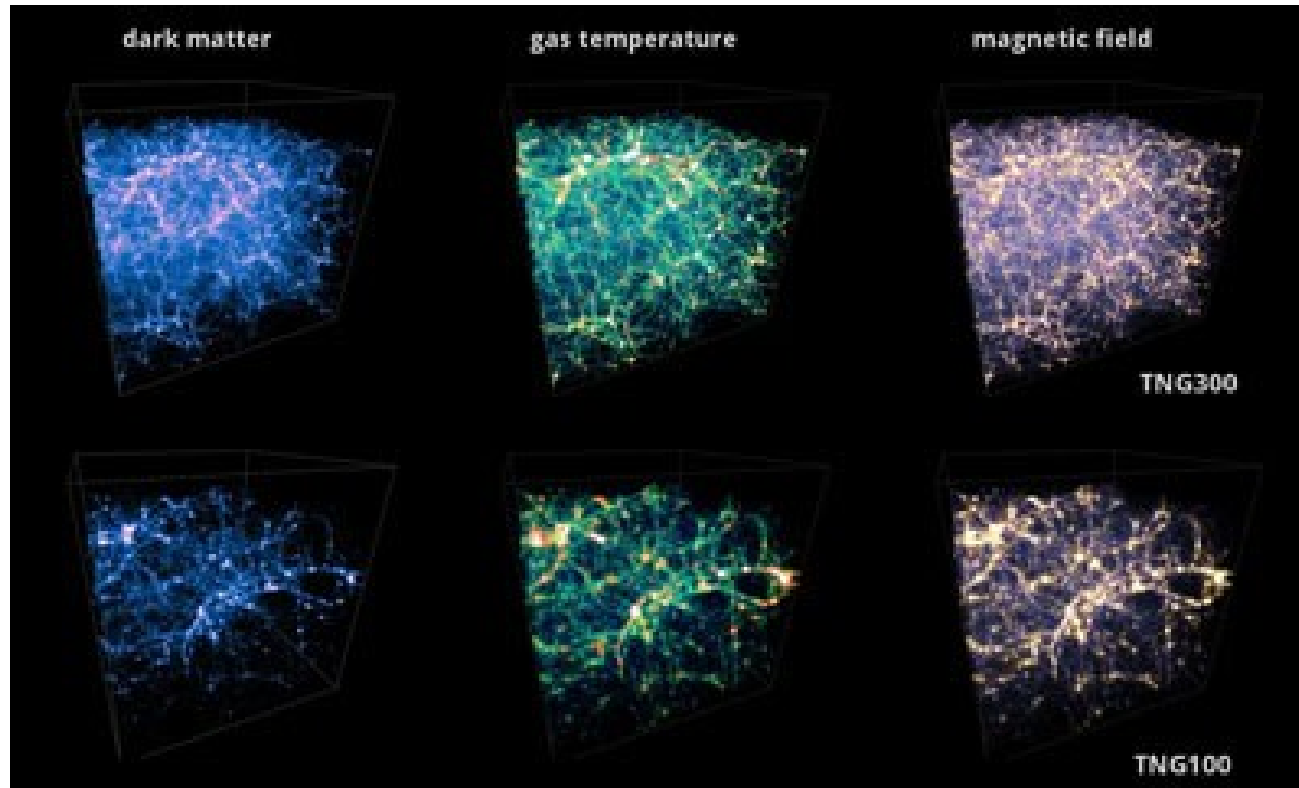
| Simulation Name  | $L_{\text{box}} [Mpc]$ | $N_{\text{DM}}$ | $m_{\text{DM}} [M_{\odot}]$ | $m_{\text{gas}} [M_{\odot}]$ | $N_{\text{snap}}$ | $N_{\text{Subfind}}(z=0)$ | Snaps | FoF | Subfind | SubLink | LHaloTree |
|------------------|------------------------|-----------------|-----------------------------|------------------------------|-------------------|---------------------------|-------|-----|---------|---------|-----------|
| TNG100-1         | 110.7                  | $1820^3$        | $7.5 \times 10^6$           | $1.4 \times 10^6$            | 100               | 4371211                   | ✓     | ✓   | ✓       | ✓       | ✓         |
| TNG100-1-Dark    | 110.7                  | $1820^3$        | $8.9 \times 10^6$           | 0                            | 100               | 5012155                   | ✓     | ✓   | ✓       | ✓       | ✓         |
| TNG300-1         | 302.6                  | $2500^3$        | $5.9 \times 10^7$           | $1.1 \times 10^7$            | 100               | 14485709                  | ✓     | ✓   | ✓       | ✓       | ✓         |
| TNG300-1-Dark    | 302.6                  | $2500^3$        | $7.0 \times 10^7$           | 0                            | 100               | 15724587                  | ✓     | ✓   | ✓       | ✓       | ✓         |
| TNG50-1          | 51.7                   | $2160^3$        | $4.5 \times 10^5$           | $8.5 \times 10^4$            | 100               | 5688113                   | ✓     | ✓   | ✓       | ✓       | ✓         |
| TNG50-1-Dark     | 51.7                   | $2160^3$        | $5.4 \times 10^5$           | 0                            | 100               | 6616159                   | ✓     | ✓   | ✓       | ✓       | ✓         |
| Illustris-1      | 106.5                  | $1820^3$        | $6.3 \times 10^6$           | $1.3 \times 10^6$            | 134               | 4366546                   | ✓     | ✓   | ✓       | ✓       | ✗         |
| Illustris-1-Dark | 106.5                  | $1820^3$        | $7.5 \times 10^6$           | 0                            | 136               | 4872374                   | ✓     | ✓   | ✓       | ✓       | ✓         |

Primary volumes: in total have **26** runs with **2814** total snapshots and **846.5 TB** total data volume, including **7,814,654,422** FoF groups, **7,397,442,543** Subfind groups, and **13,554,923,373,776** particles.

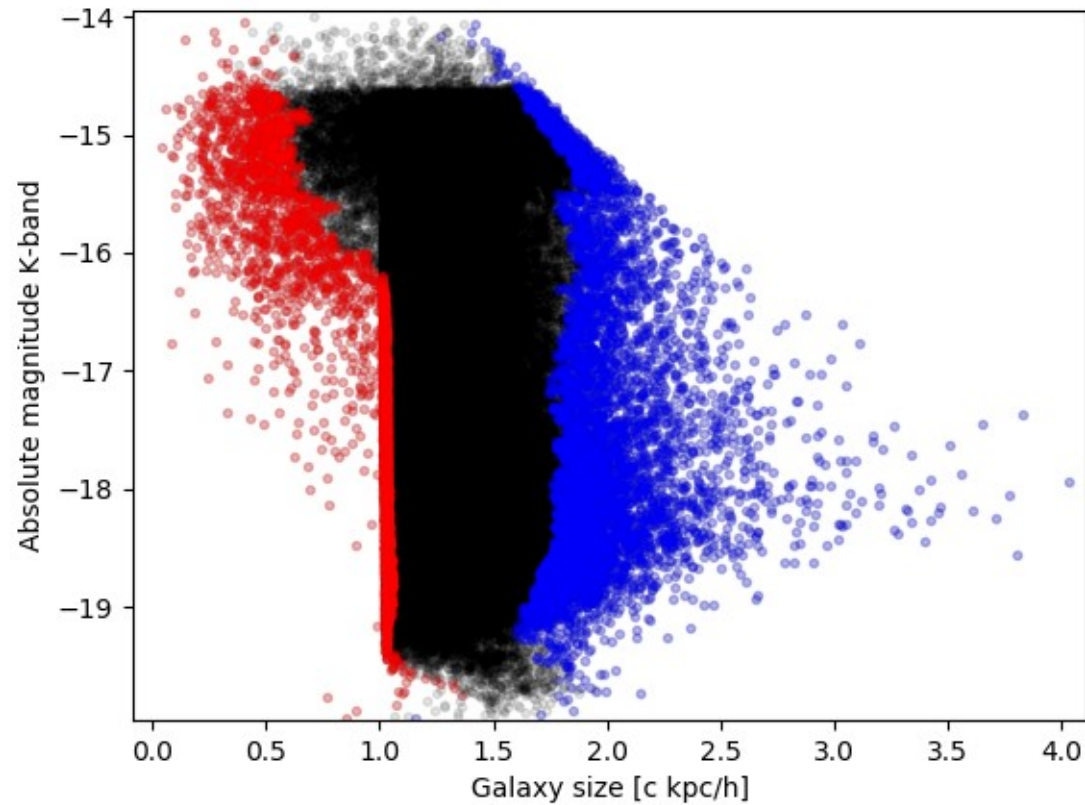
Selection of low and high surface brightness galaxies from  
Illustris TNG-300-1 simulation



Selection of low and high surface brightness galaxies from  
Illustris TNG-300-1 simulation

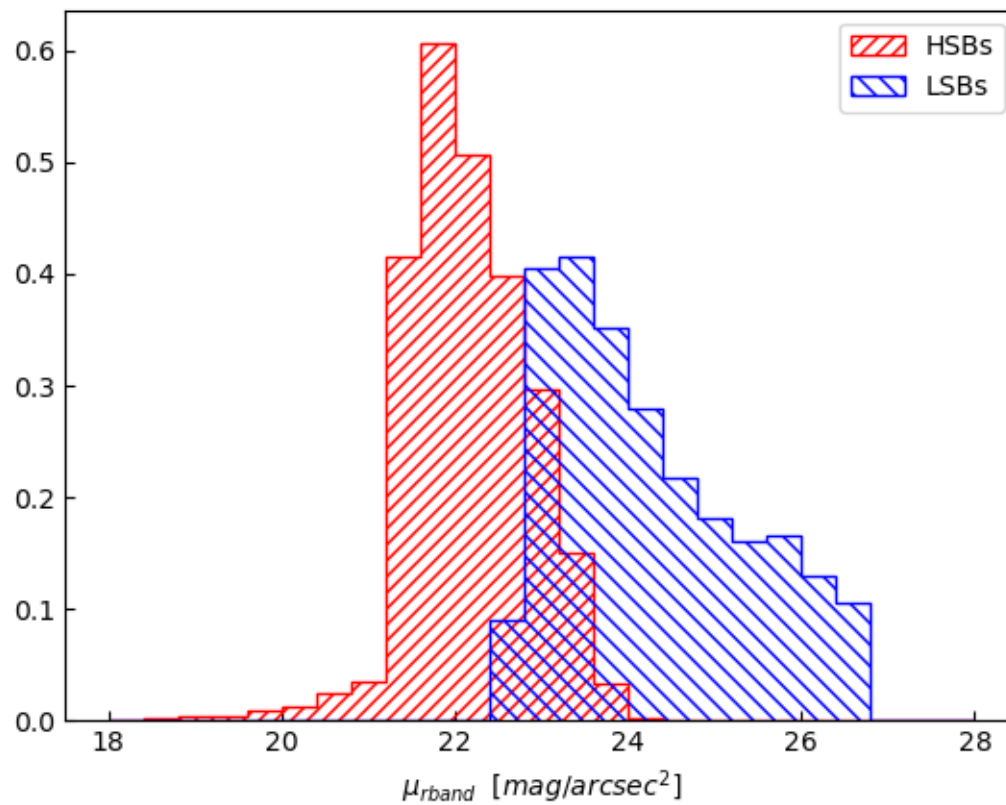


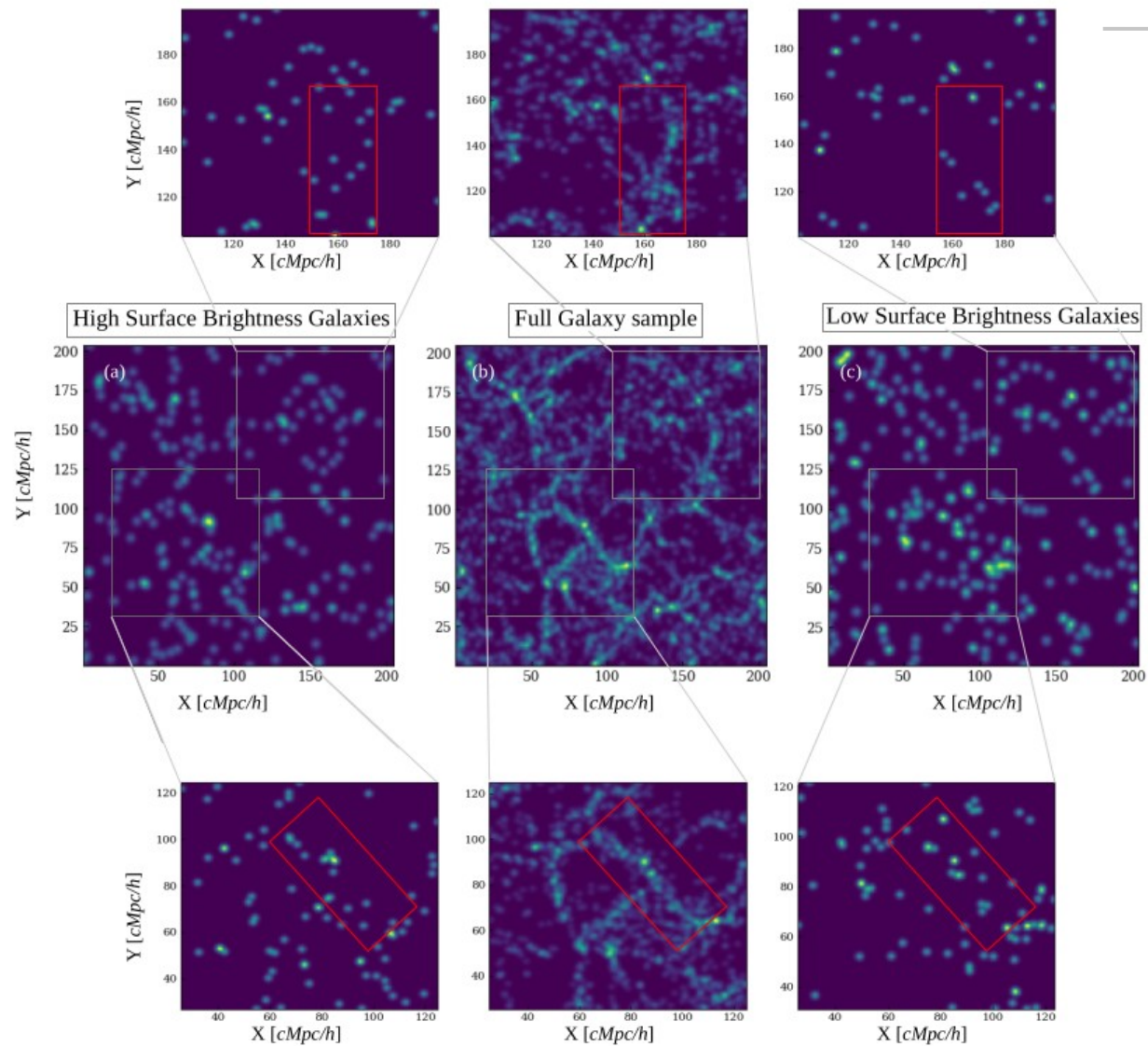
Selection of low and high surface brightness galaxies from  
Illustris TNG-300-1 simulation





Surface brightness distribution of galaxy samples from  
Illustris TNG-300-1 simulation





## OPEN QUESTIONS

The origin and evolution of LSBGs remains unclear...

Are LSBGs just the low brightness end in the galaxy luminosity distribution?

LSBGs has high content of dark matter...

Assuming two dark matter halos with the same mass content, does its properties changes with the properties of their central galaxy?

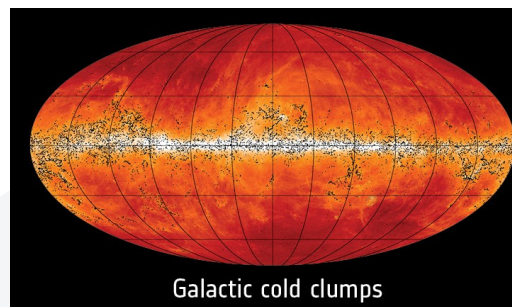
Does LSBGs large-scale distribution follows the pattern of the known cosmic web?

What is the origin of giant LSBGs?

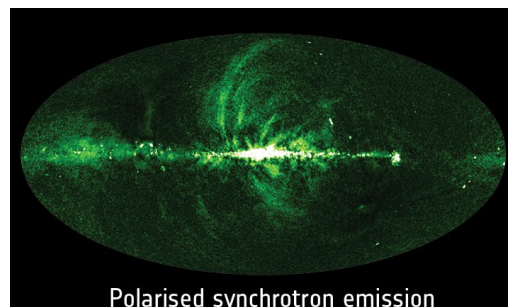


## **IV. CMB and nearby galaxies**

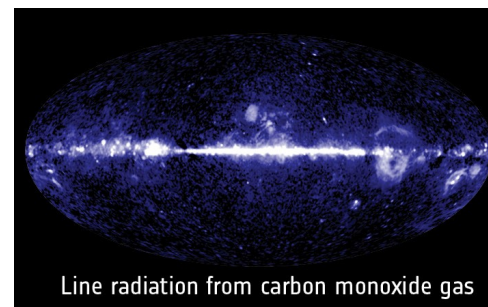
*CMB foregrounds consist of all interactions that affect the path or the energy of the photons between the surface of last scattering and the detectors, which can interfere with the cosmological interpretation of CMB data (most conservative definition).*



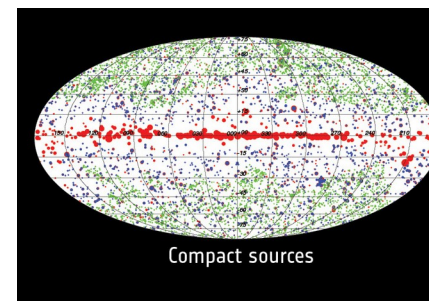
Galactic cold clumps



Polarised synchrotron emission



Line radiation from carbon monoxide gas



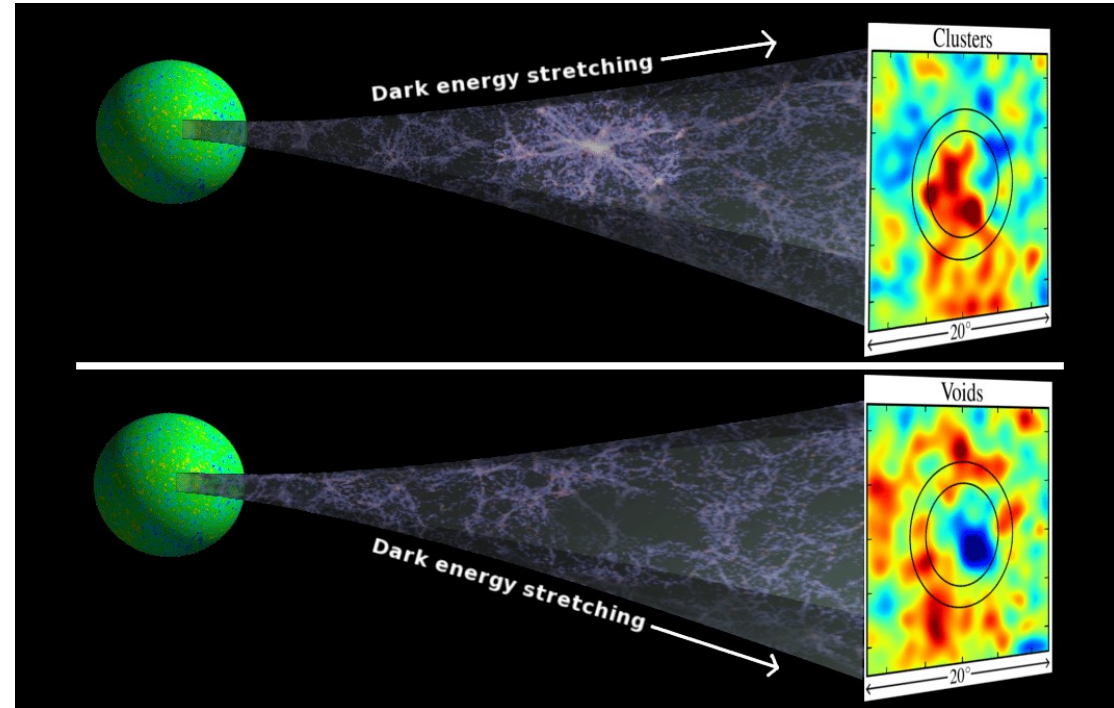
Compact sources

- \* diffuse components in our galaxy: thermal dust emission, line radiation from carbon monoxide gas, diffuse synchrotron emission, and free-free emission
- \* point-like or compact sources of emission: from pre-stellar cores to galaxy clusters in a wide range of distances



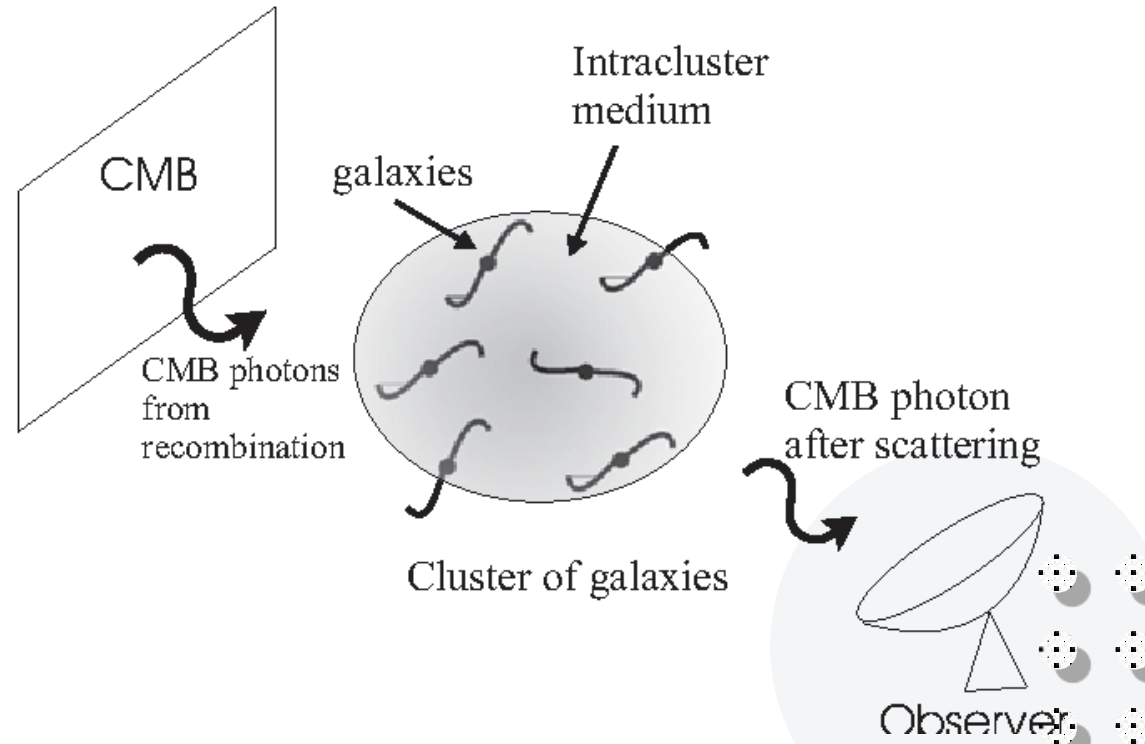
## Integrated Sachs-Wolfe effect \* (*foreground/secondary anisotropy*)

- \* produced by evolving potentials
- \* gain or lose of energy depending on large-scale over/underdensities
- \* uneven fluctuations of about 10 degrees
- \* best detection at  $z \sim 0.3$
- \* not removed from CMB data

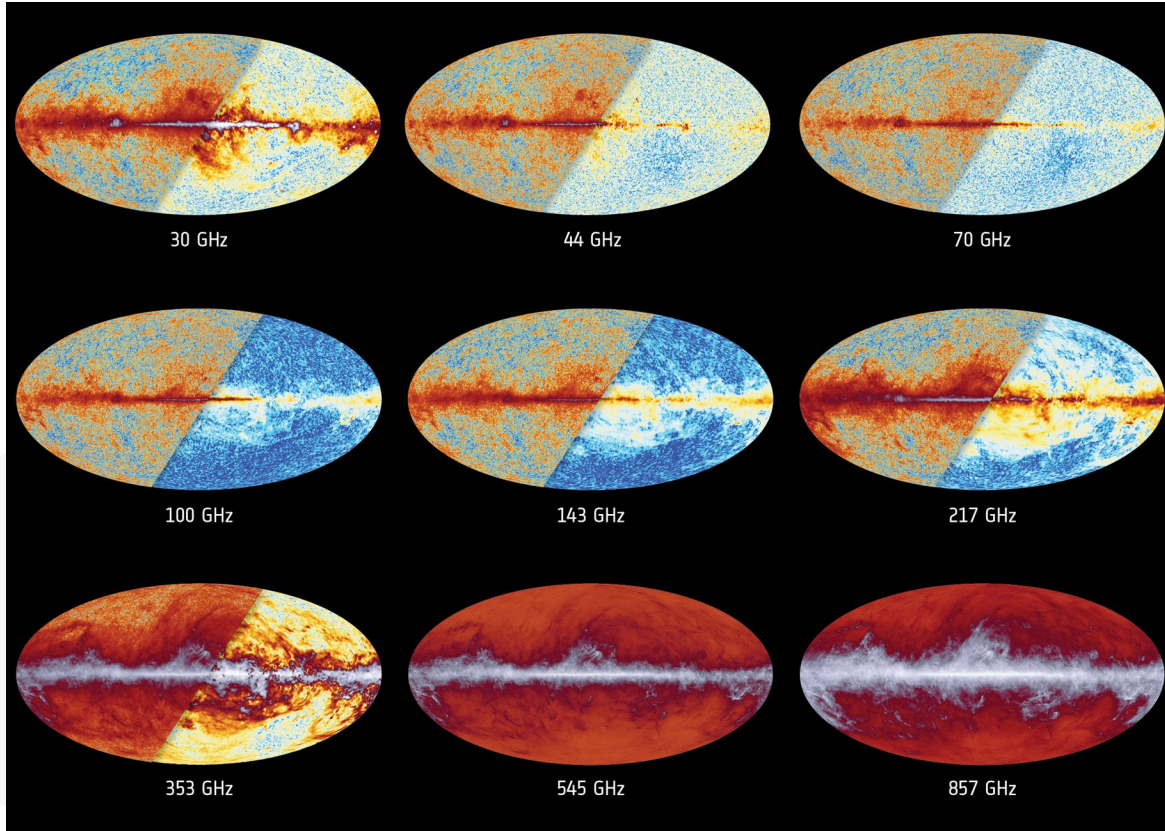


## Thermal Sunyaev-Zeldovich effect \* (foreground/secondary anisotropy)

- \* spectral distortion of the CMB through inverse Compton scattering by high-energy electrons
- \* associated to massive galactic clusters
- \* independent of  $z$
- \* can be extracted from the CMB data



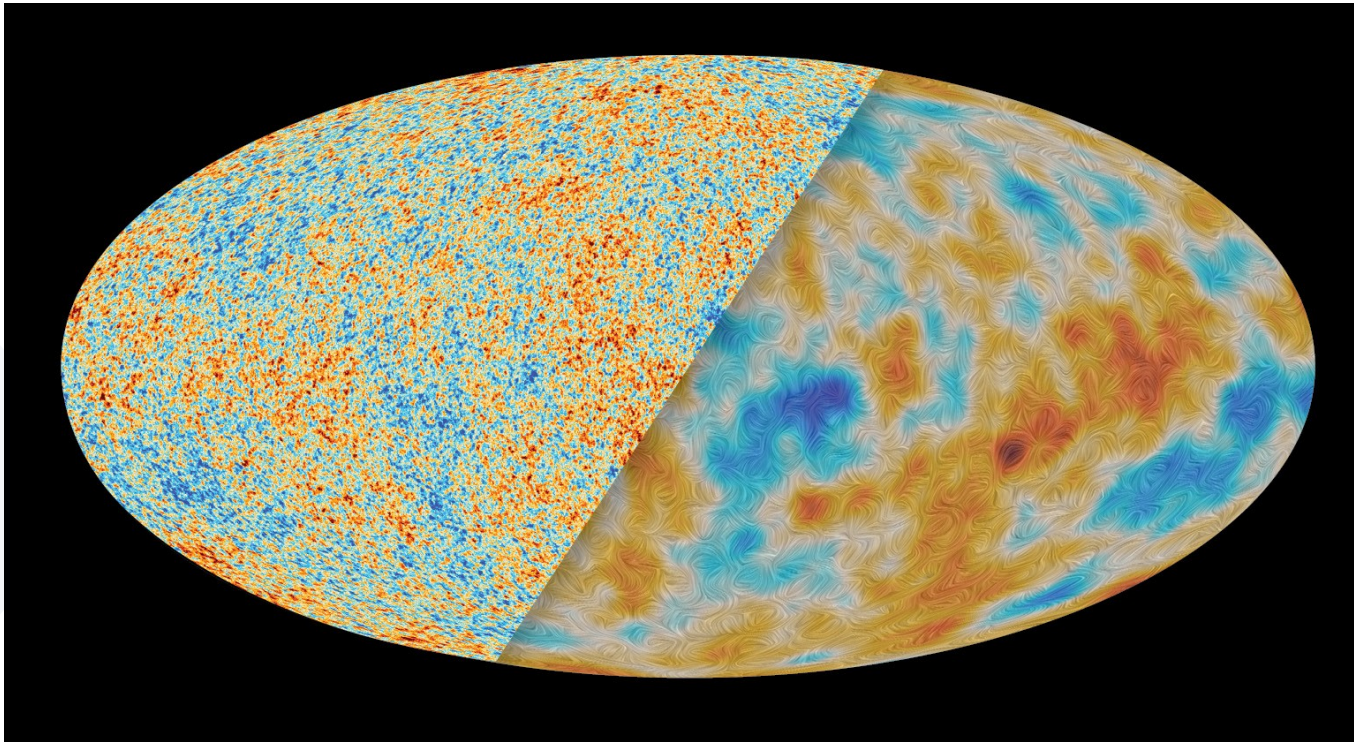
Plank provides data for 9 frequency bands



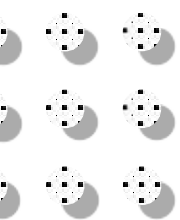
## SMICA (*Spectral Matching Independent Component Analysis*)

- \* 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

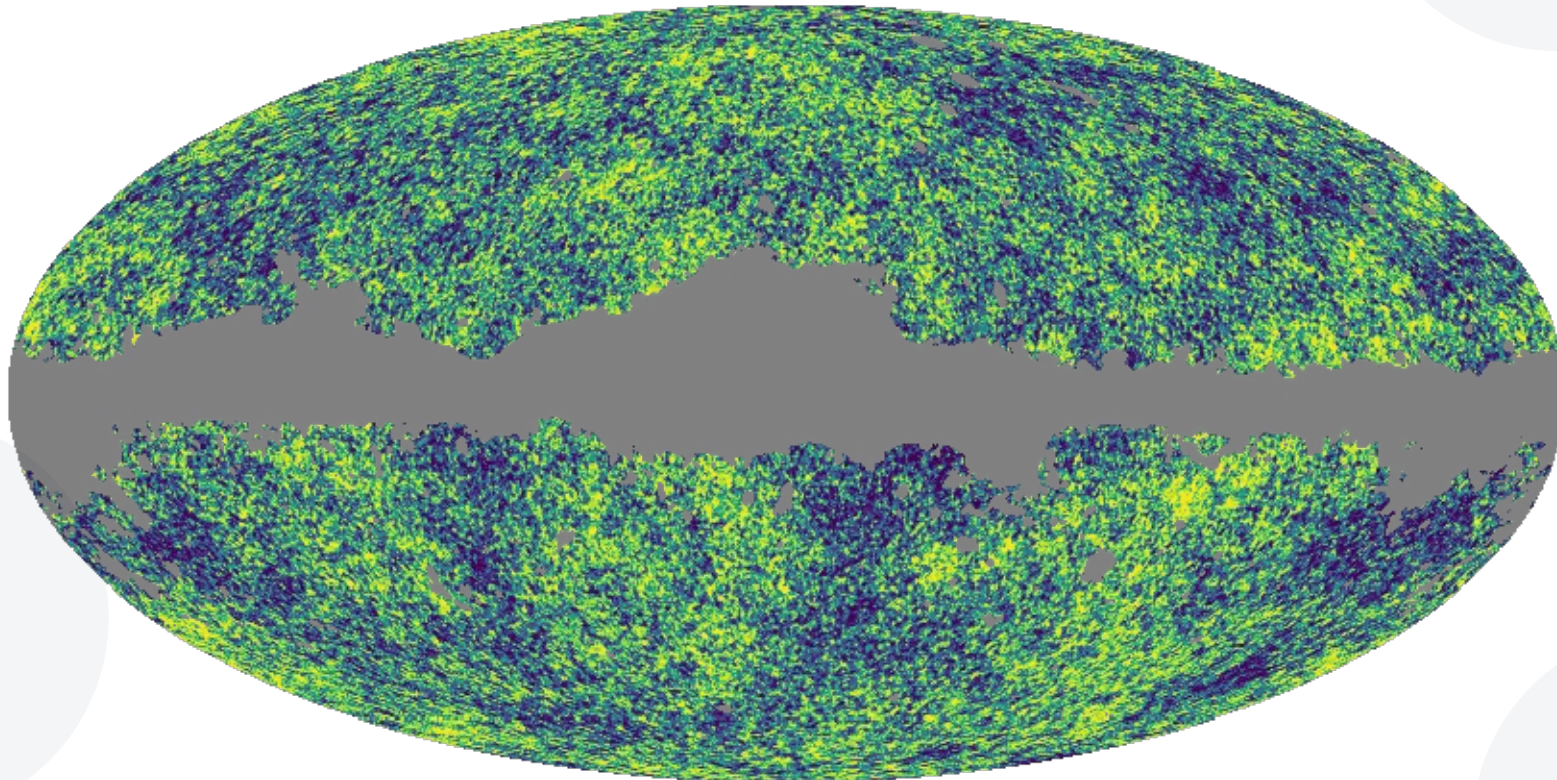
By analysing the **primordial anisotropies**, satellite experiments as Planck have put strong constraints on cosmological parameters. Such cosmological information is available only when sources contaminating the estimation of CMB are removed successfully.





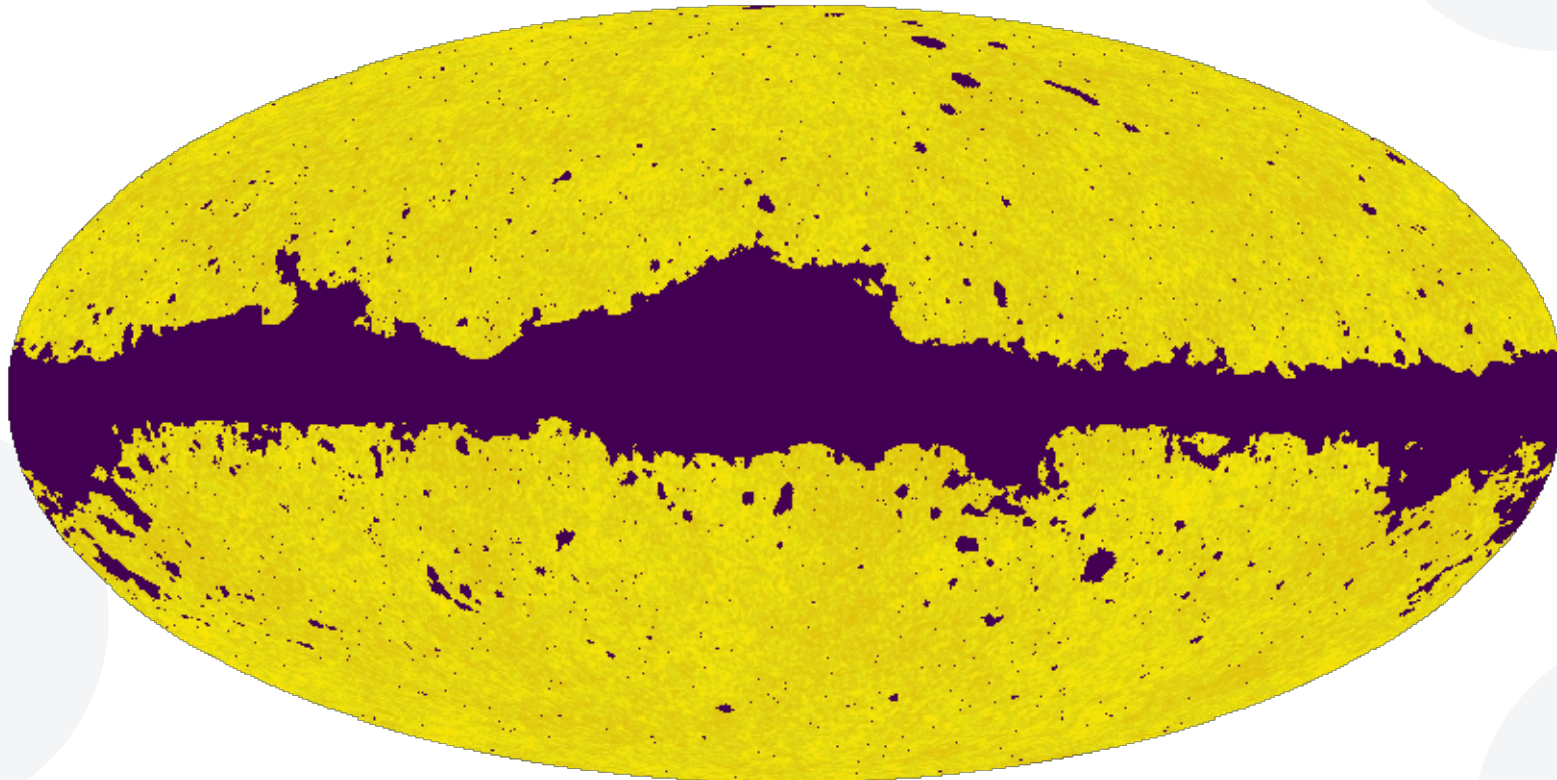


**CMB SMICA Intensity map + Common mask** (*Planck Collaboration 2020*) -  $N_{\text{side}}=2048$





CMB SMICA Intensity map + Common mask (Planck Collaboration 2020) -  $N_{\text{side}}=2048$



## 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

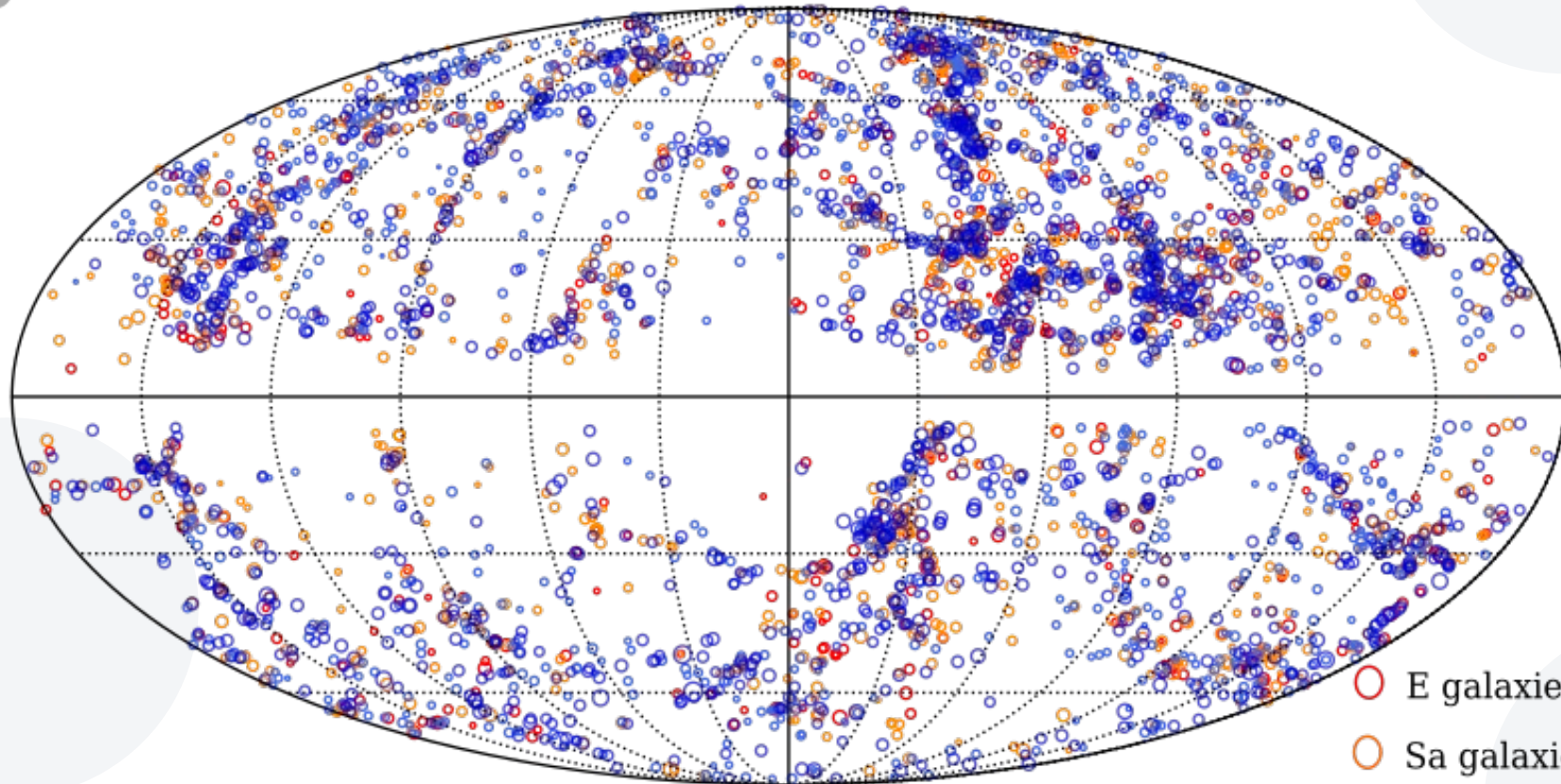
Nearby galaxy samples ( $0.001 < z < 0.015$ ) according to the morphological types:

(Late type spirals)

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

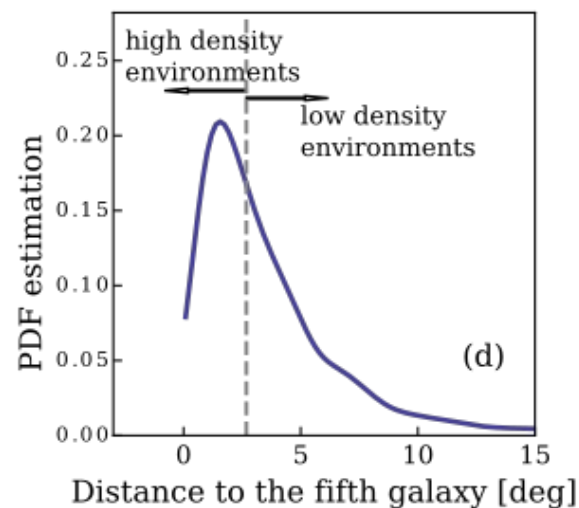
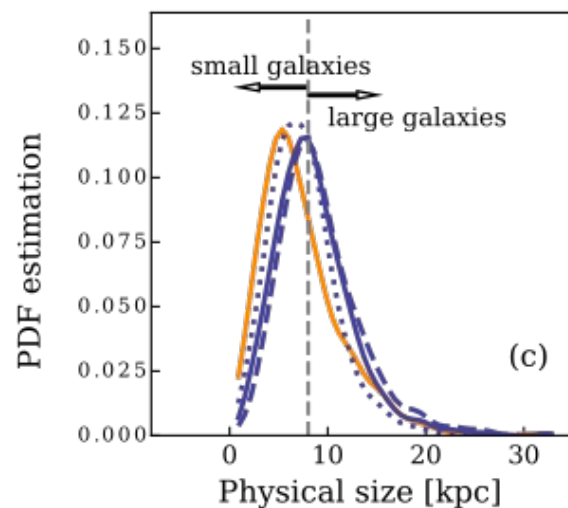
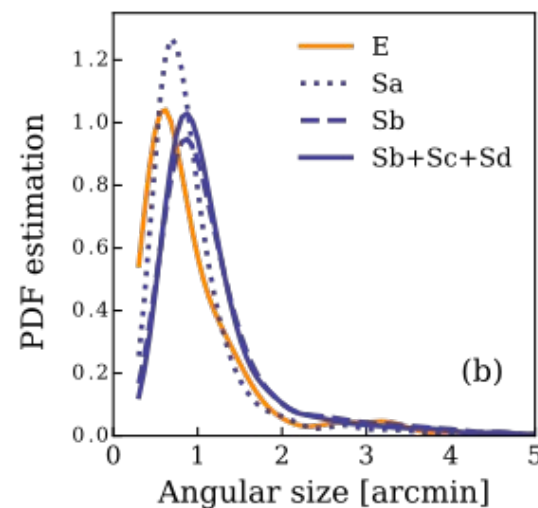
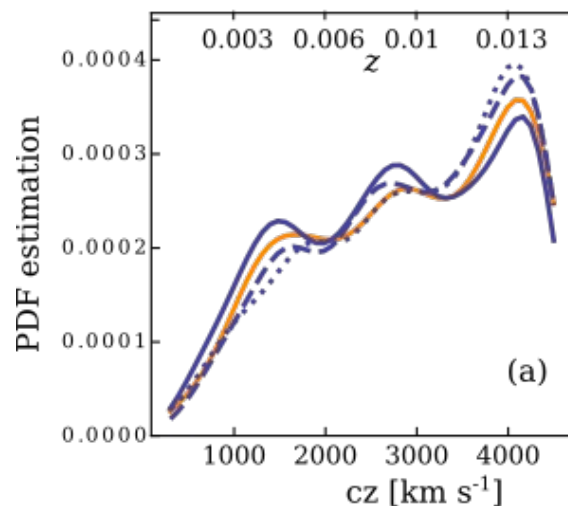


## 2MRS galaxy distribution

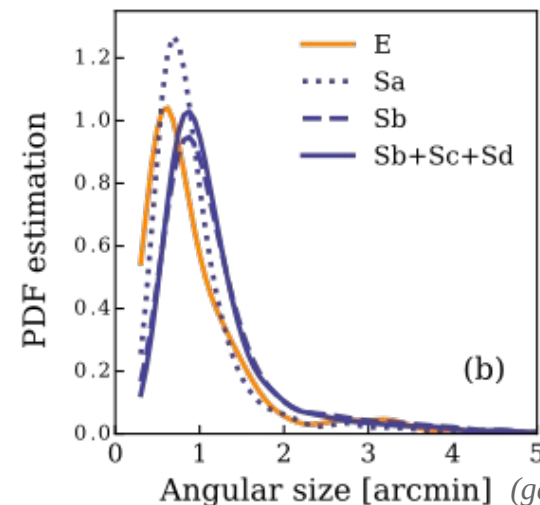
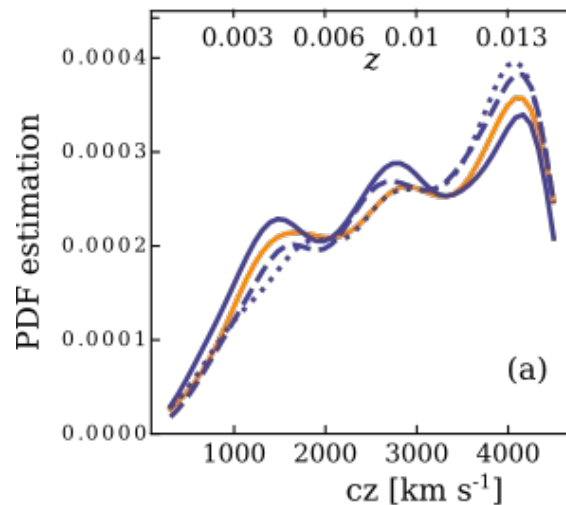


- E galaxies
- Sa galaxies
- Sb + Sc + Sd galaxies

no bias  
associated  
with sample  
depths

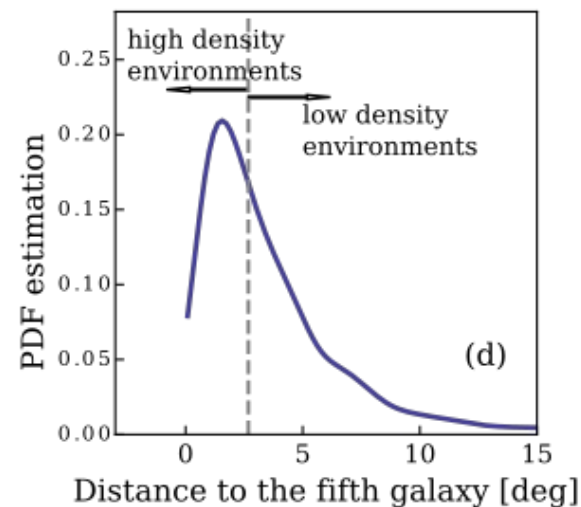
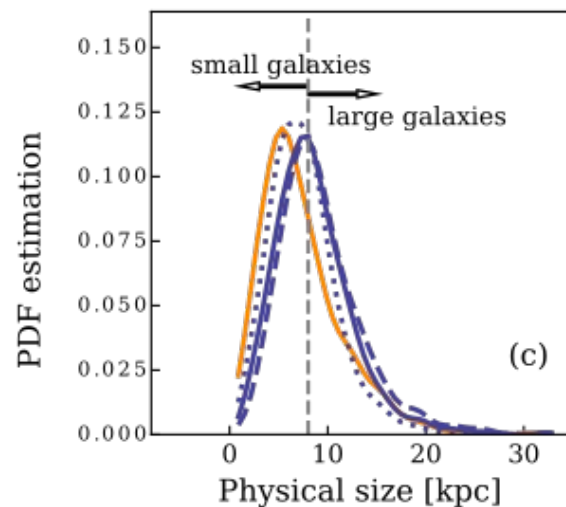


no bias  
associated  
with sample  
depths



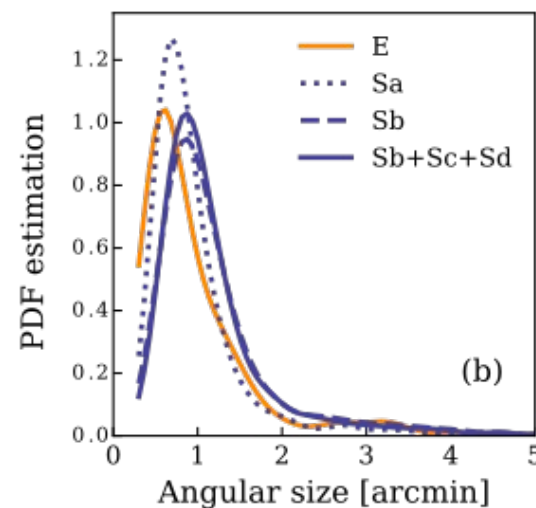
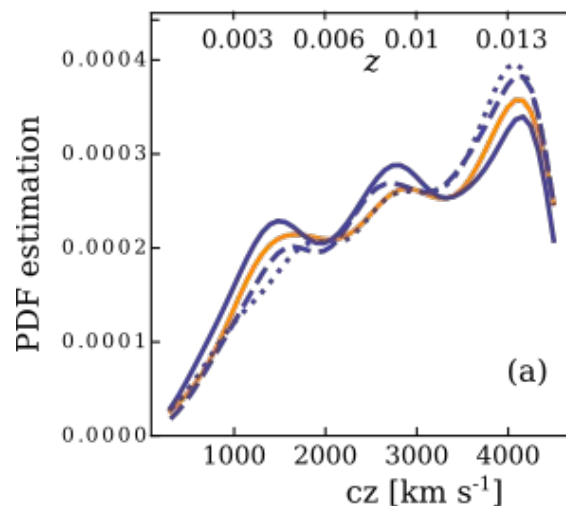
(CMB pixel resolution 1.7 arcmin)

Spiral galaxies are a little large than Elliptical, but there are not significant differences.

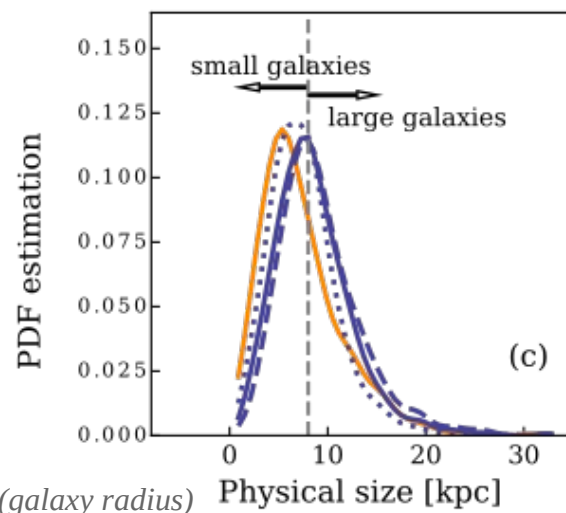




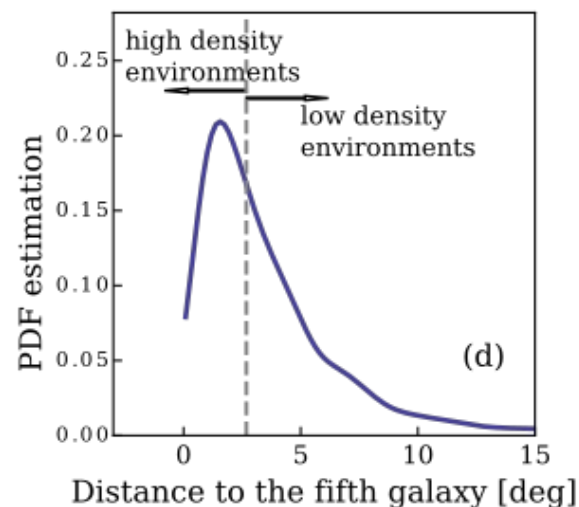
no bias  
associated  
with sample  
depths



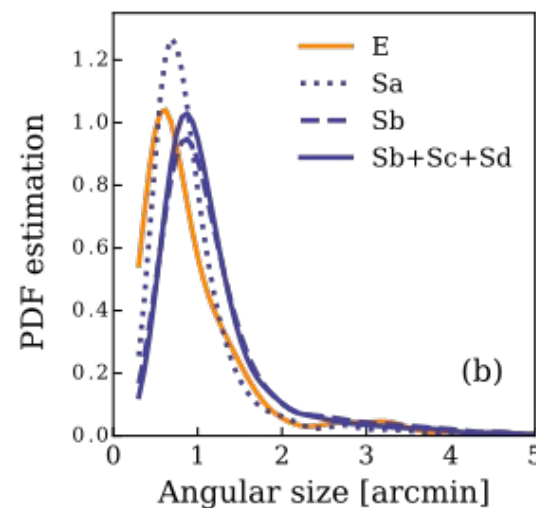
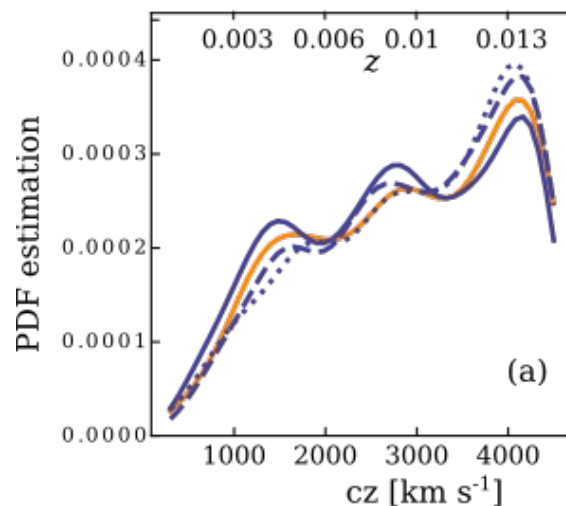
Spiral galaxies are a little large than Elliptical, but there are not significant differences.



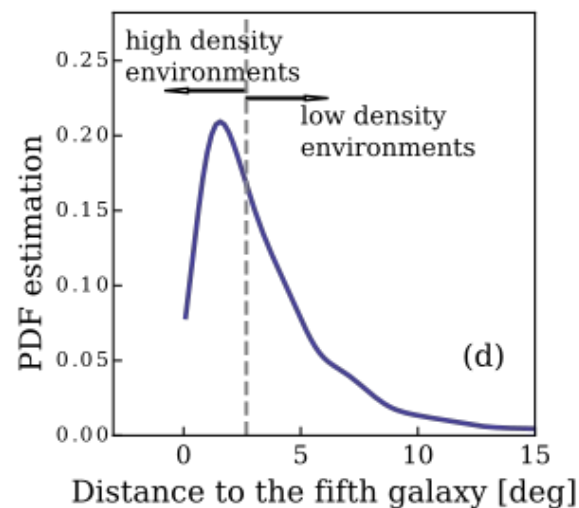
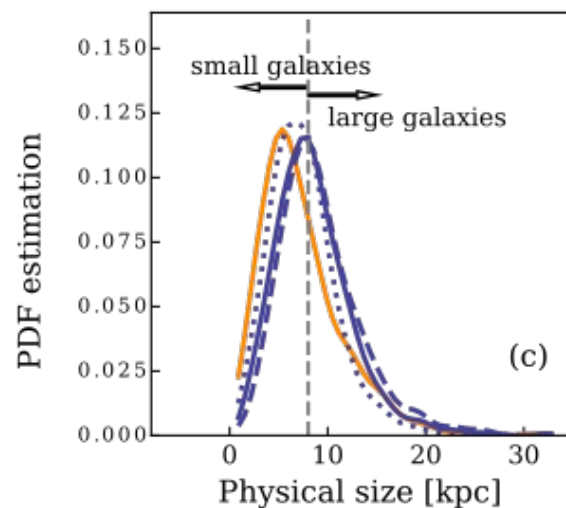
(galaxy radius)



no bias  
associated  
with sample  
depths



Spiral galaxies are a little large than Elliptical, but there are not significant differences.

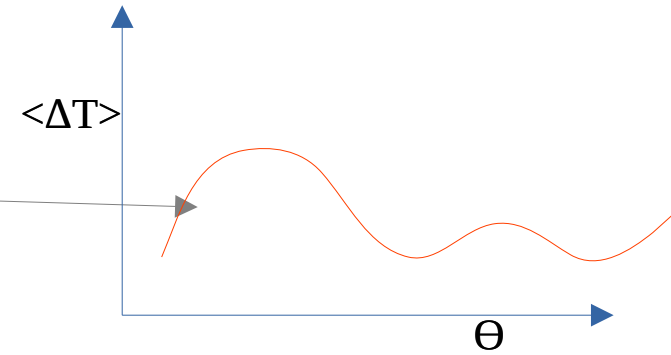
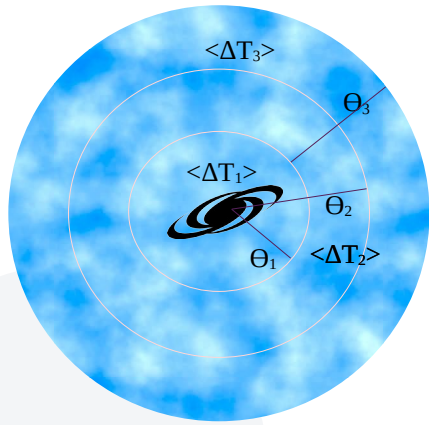


Calculation of the averaged radial profile for the samples

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

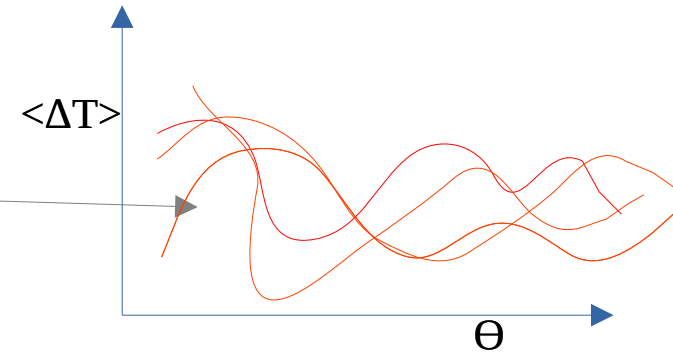
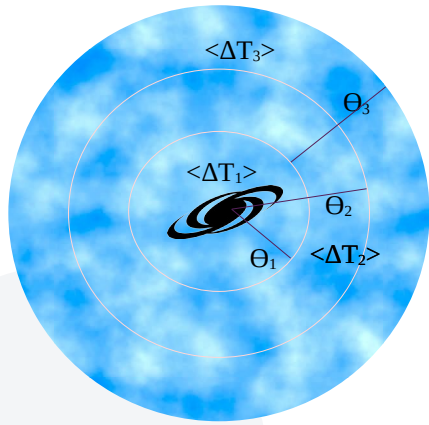
Calculation of the averaged radial profile for the samples

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



Calculation of the averaged radial profile for the samples

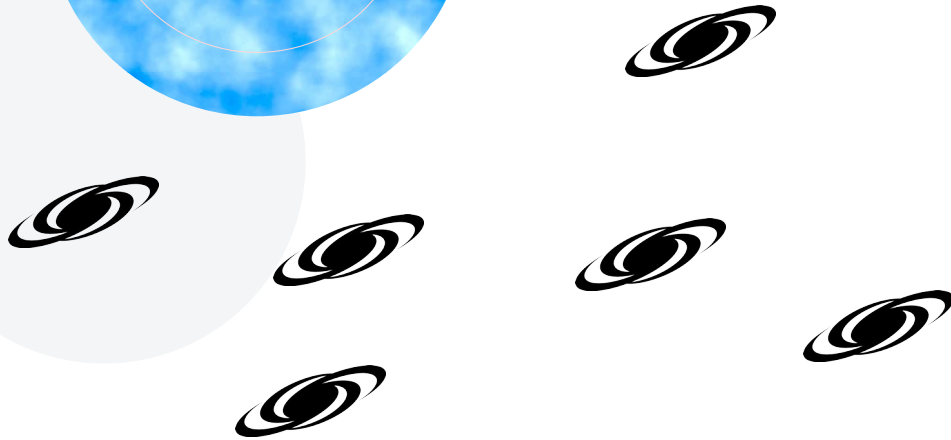
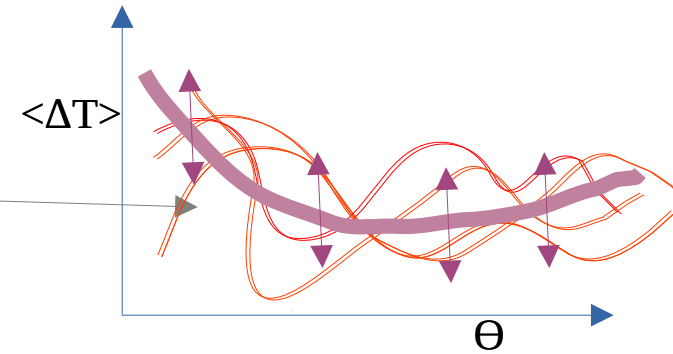
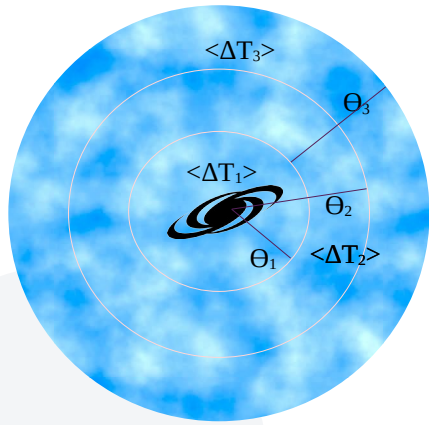
$$\langle \Delta T \rangle (\theta) = \frac{1}{N_{\text{gxs}}} \sum_{k=1}^{N_{\text{gxs}}} \left( \frac{1}{N_k} \sum_{i \in C_k} \Delta T(k, i) \right),$$





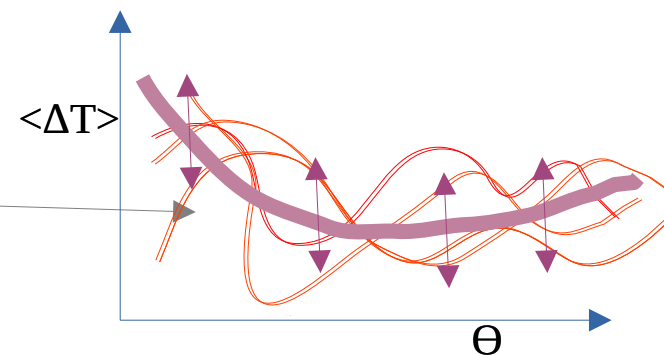
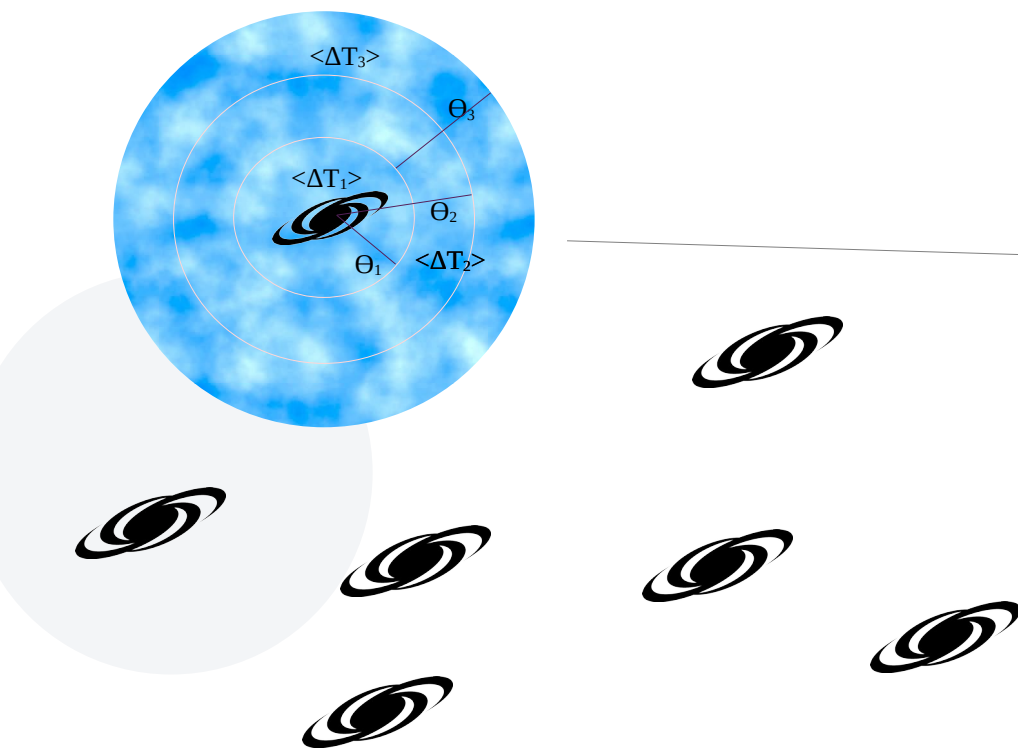
## Calculation of the averaged radial profile for the samples

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



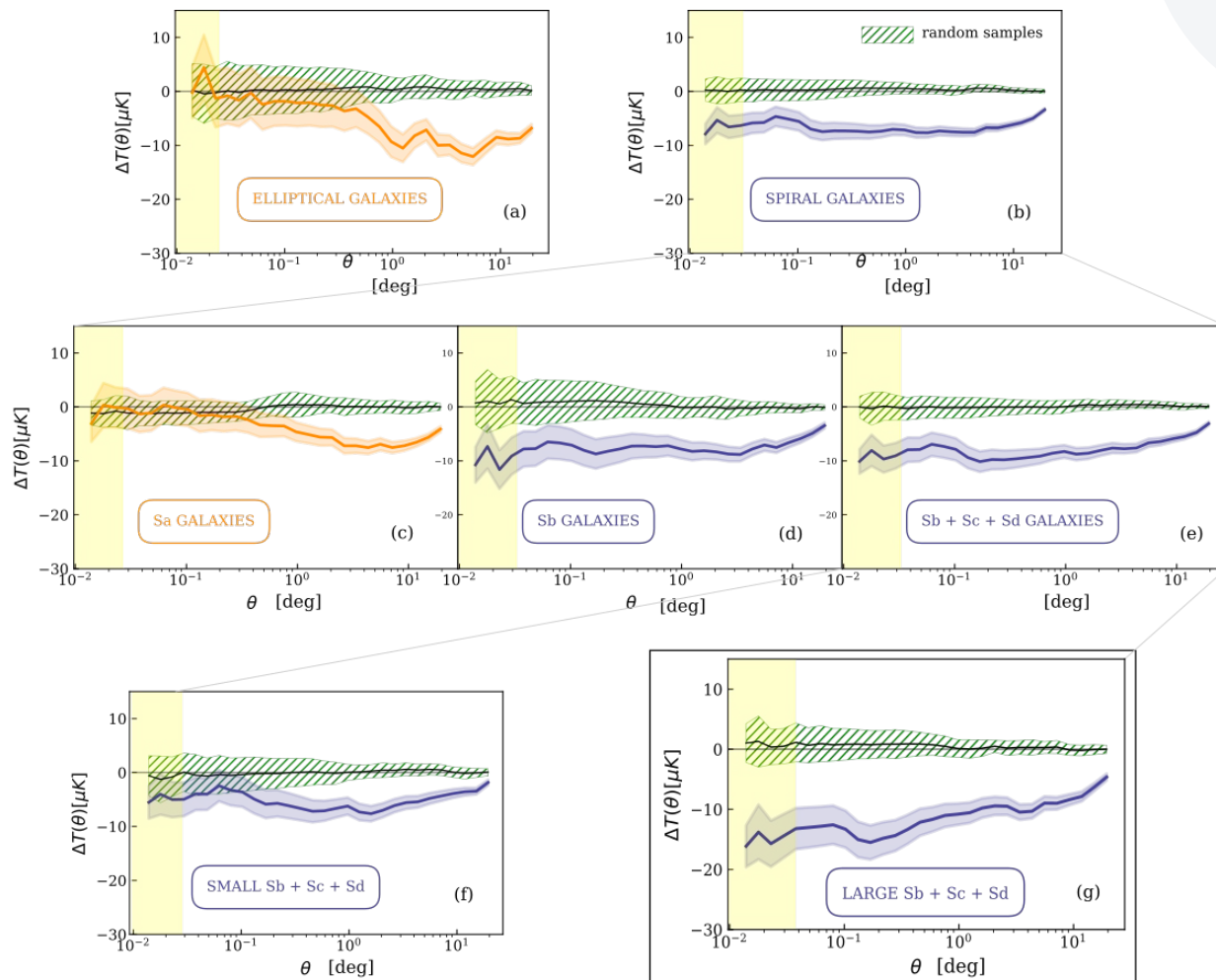
## Calculation of the averaged radial profile for the samples

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

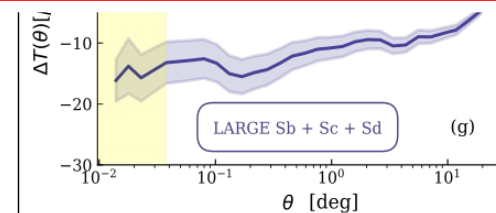
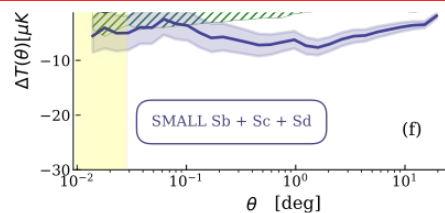
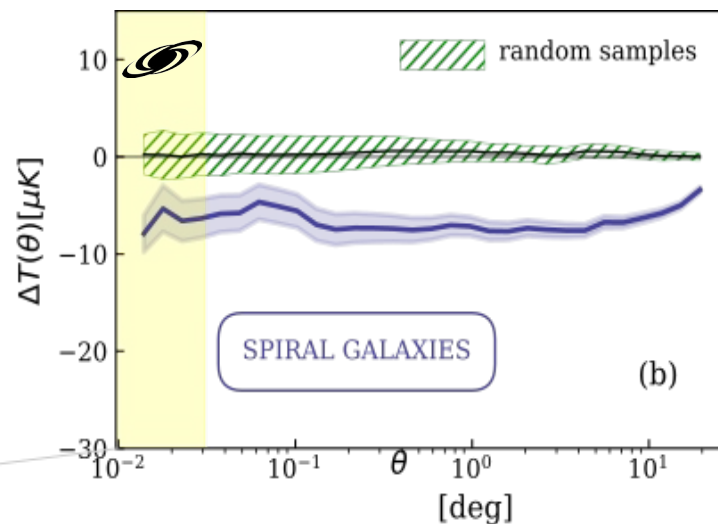
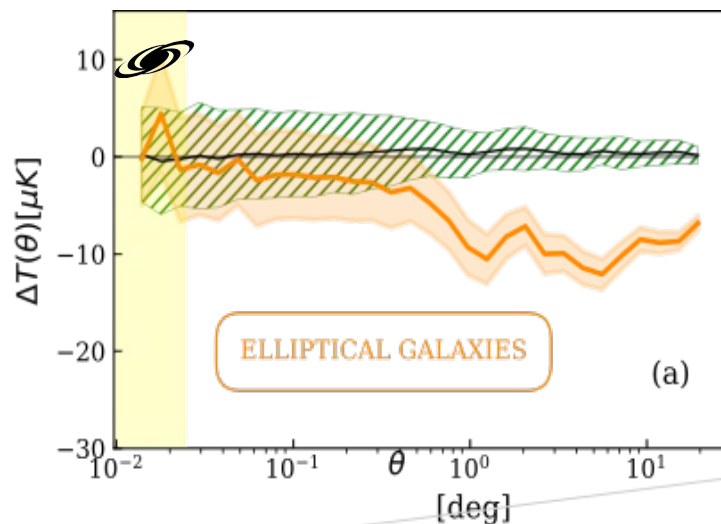
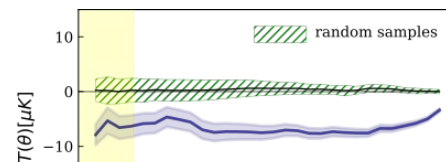
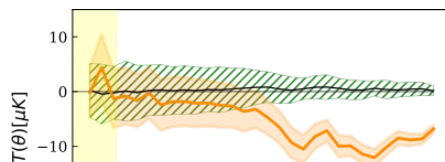


+ 20 random realizations with the same number of objects in the same area to estimate the mean and standard deviation of the control sample

## Temperature profile for the galaxy samples



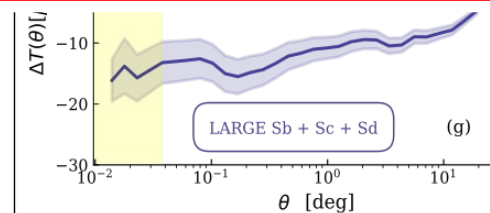
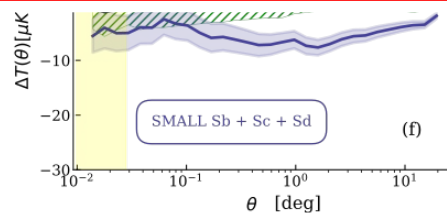
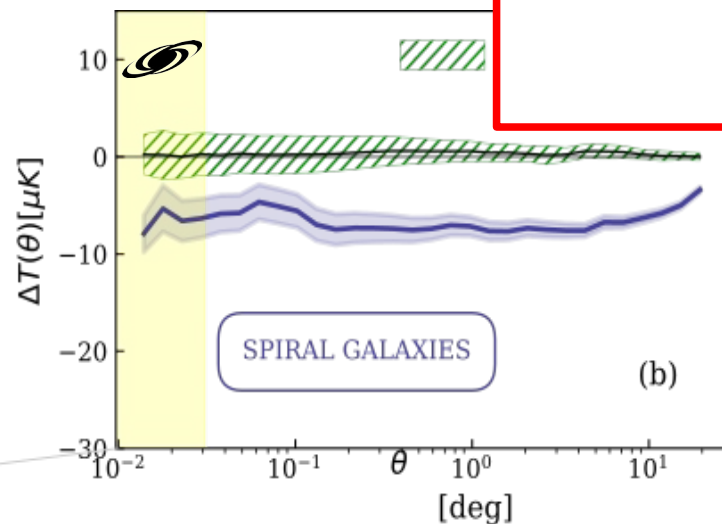
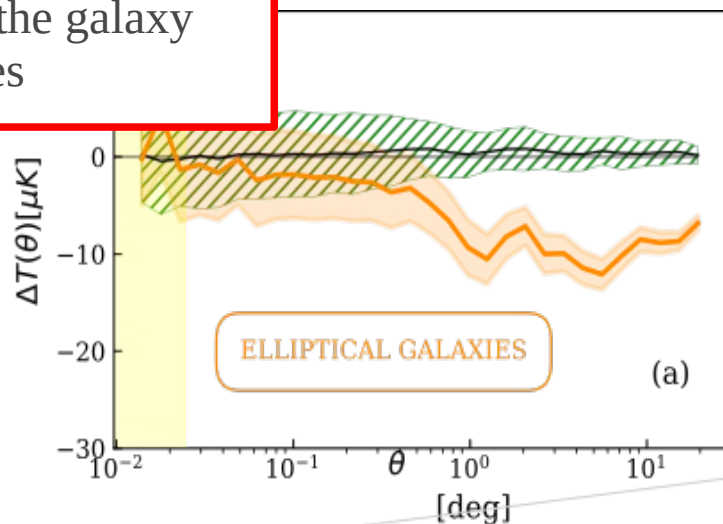
## Temperature profile for the galaxy samples



# Temperature profile for the galaxy samples

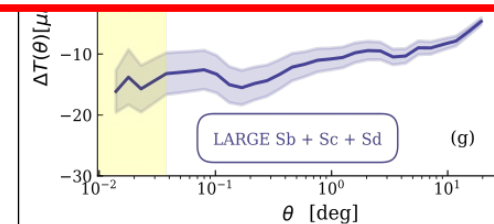
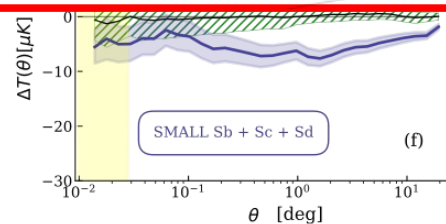
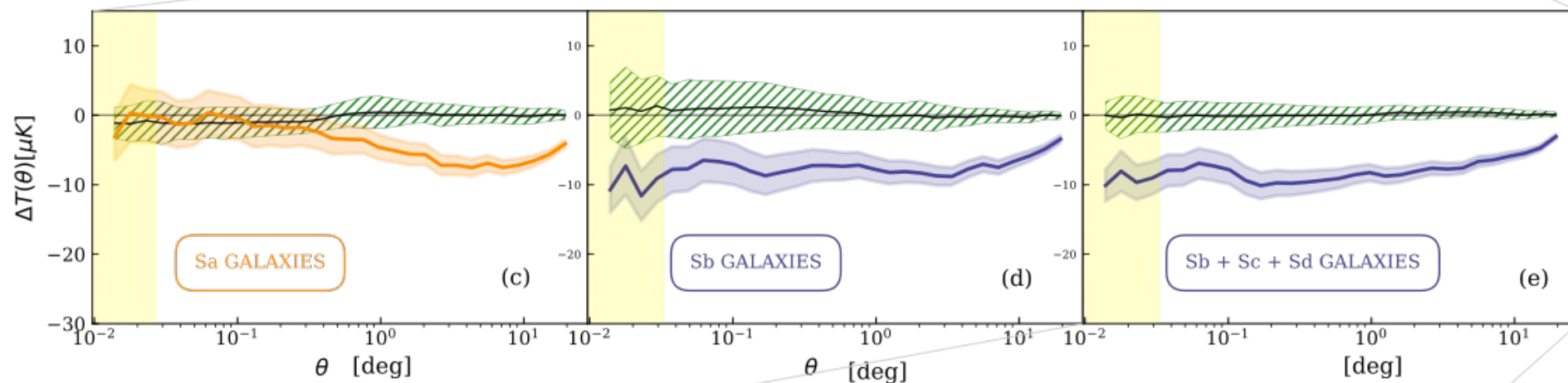
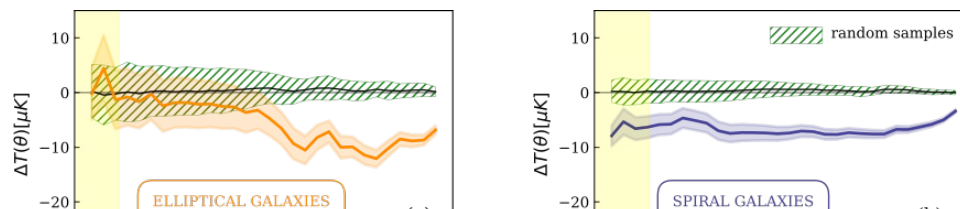
Elliptical galaxies only differ from random samples at large distances from the galaxy centres

Spiral galaxies have a significant signal decrement

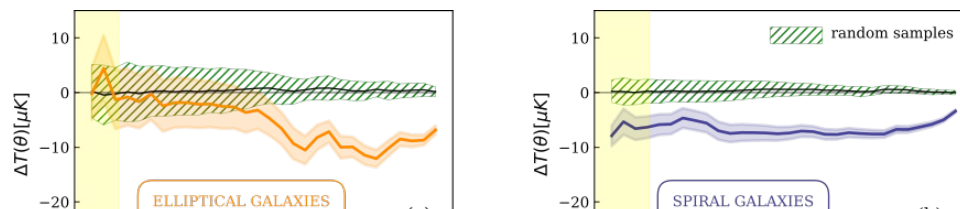




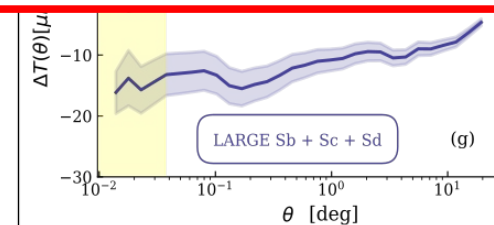
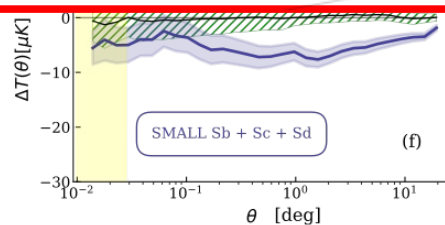
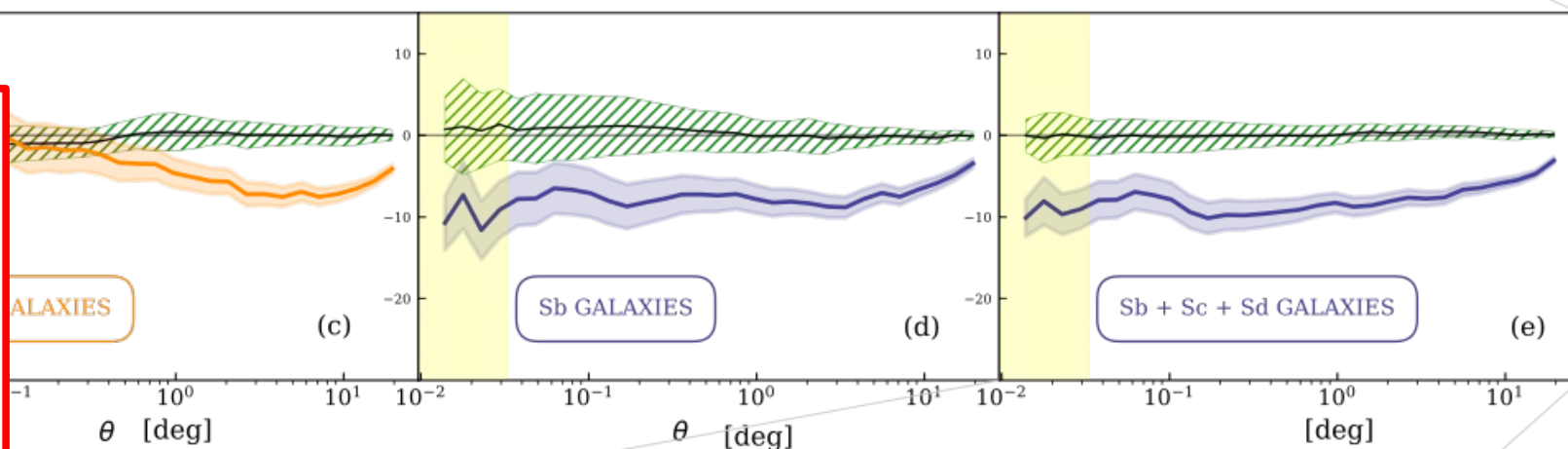
## Temperature profile for the galaxy samples



# Temperature profile for the galaxy samples

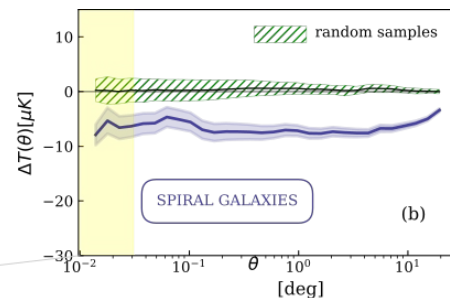
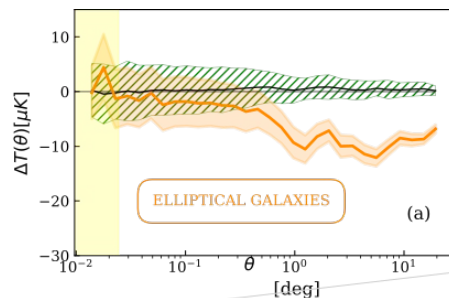


the observed signal is arising from the late type Spiral galaxies

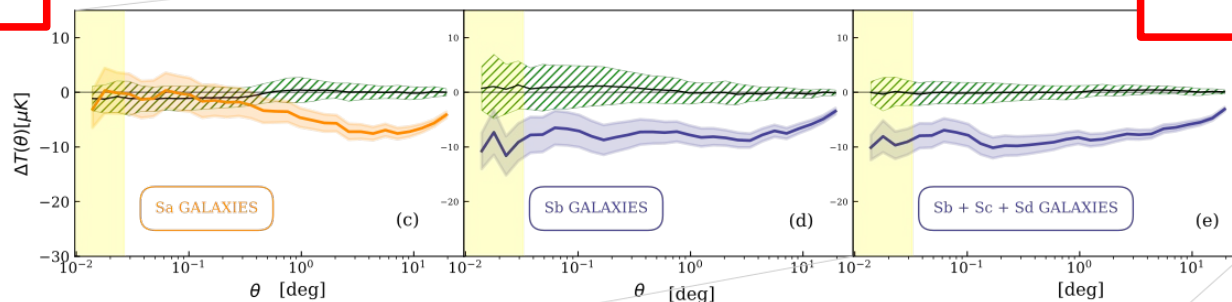


## Temperature profile for the galaxy samples

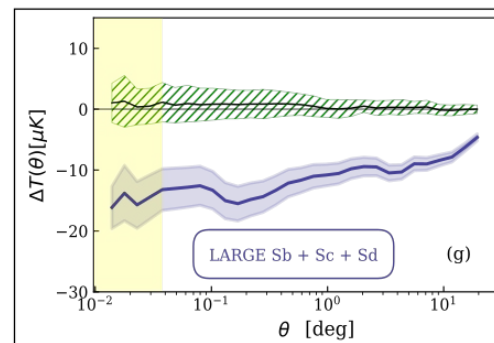
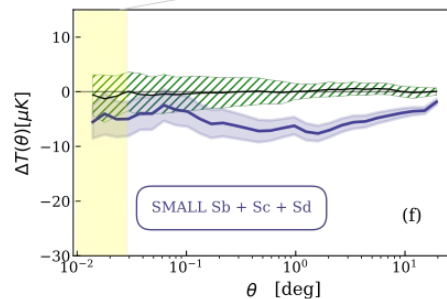
Elliptical galaxies only differ from random samples at large distances from the galaxy centres



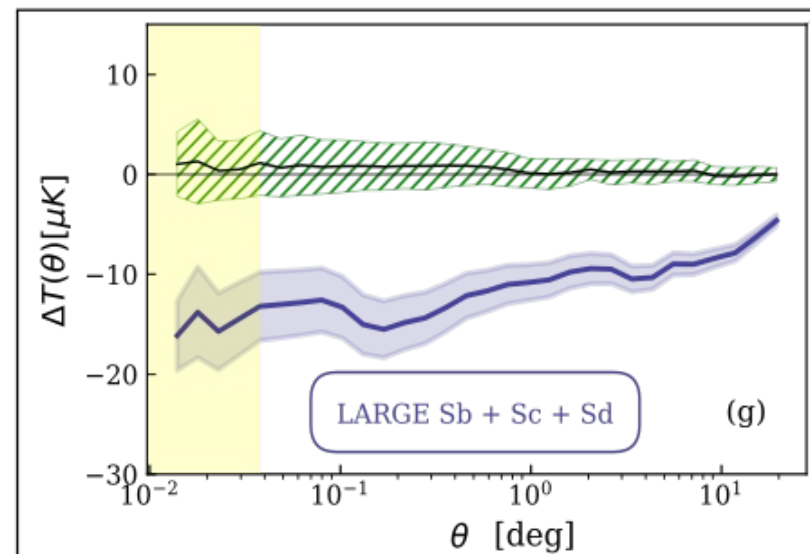
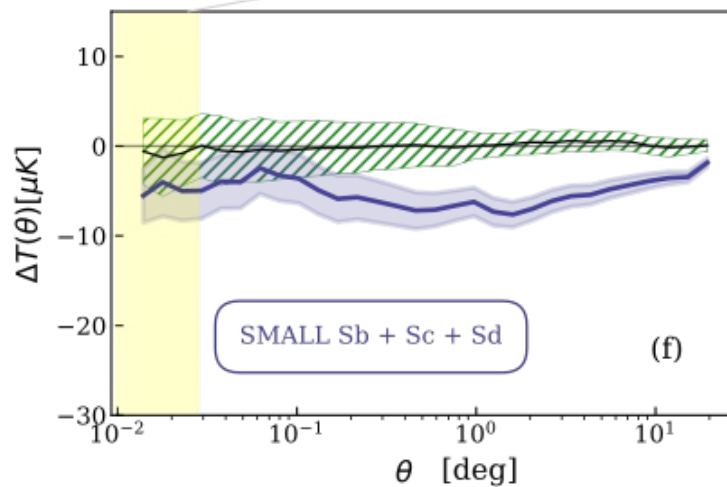
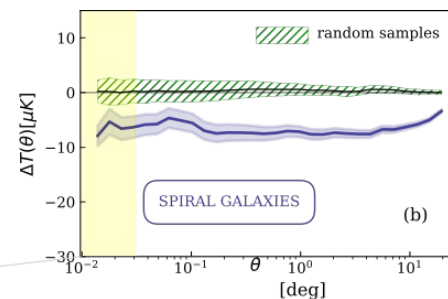
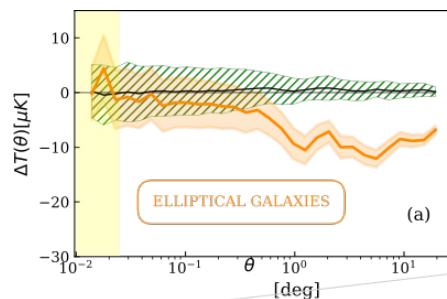
Spiral galaxies have a significant signal decrement



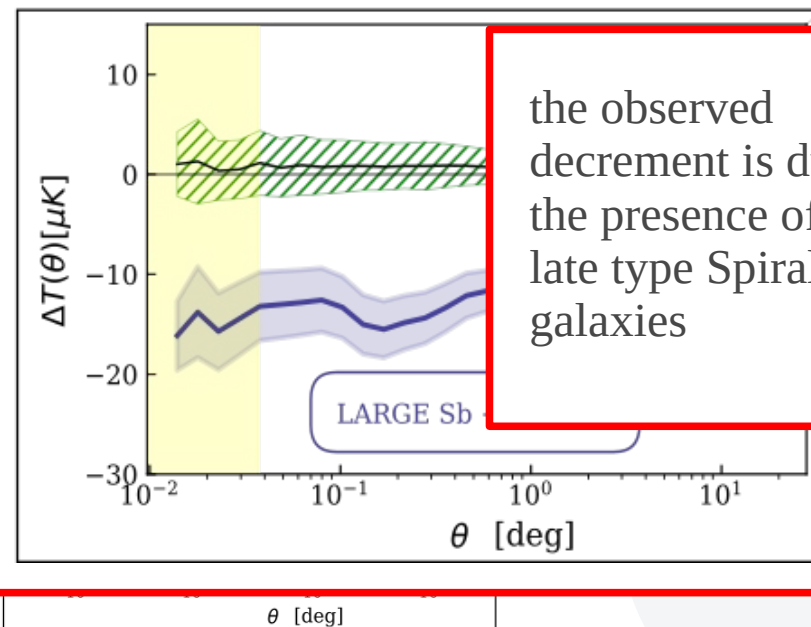
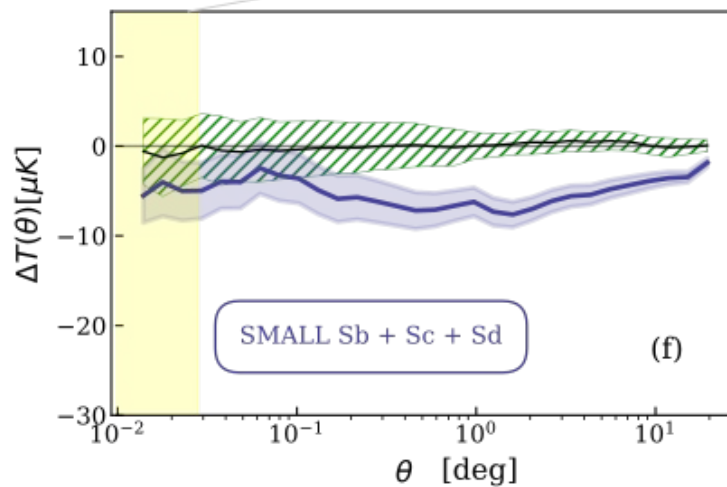
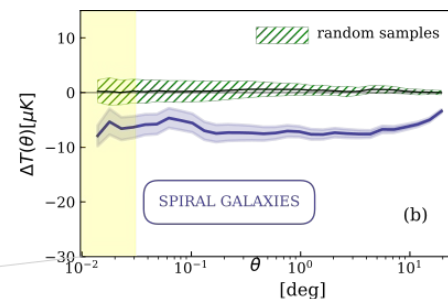
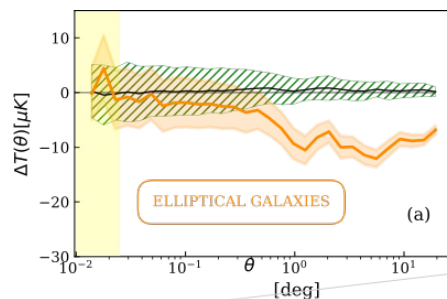
the observed signal is arising from the late type Spiral galaxies



## Temperature profile for the galaxy samples



## Temperature profile for the galaxy samples



the observed decrement is due to the presence of large late type Spiral galaxies



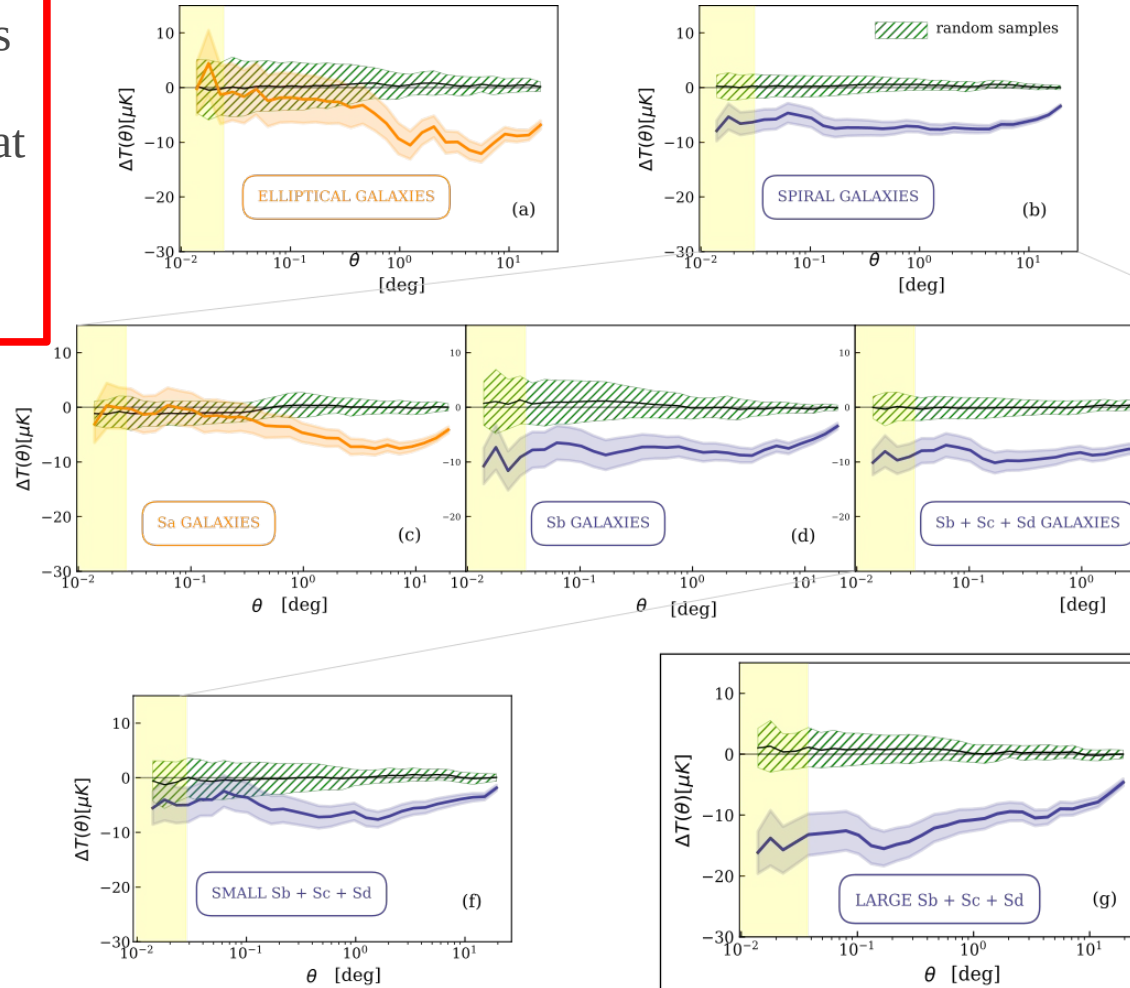
## Temperature profile for the galaxy samples

Elliptical galaxies only differ from random samples at large distances from the galaxy centres

the observed signal is arising from the late type Spiral galaxies

Spiral galaxies have a significant signal decrement

the observed decrement is due to the presence of large late type Spiral galaxies



## Temperature profile for the galaxy samples

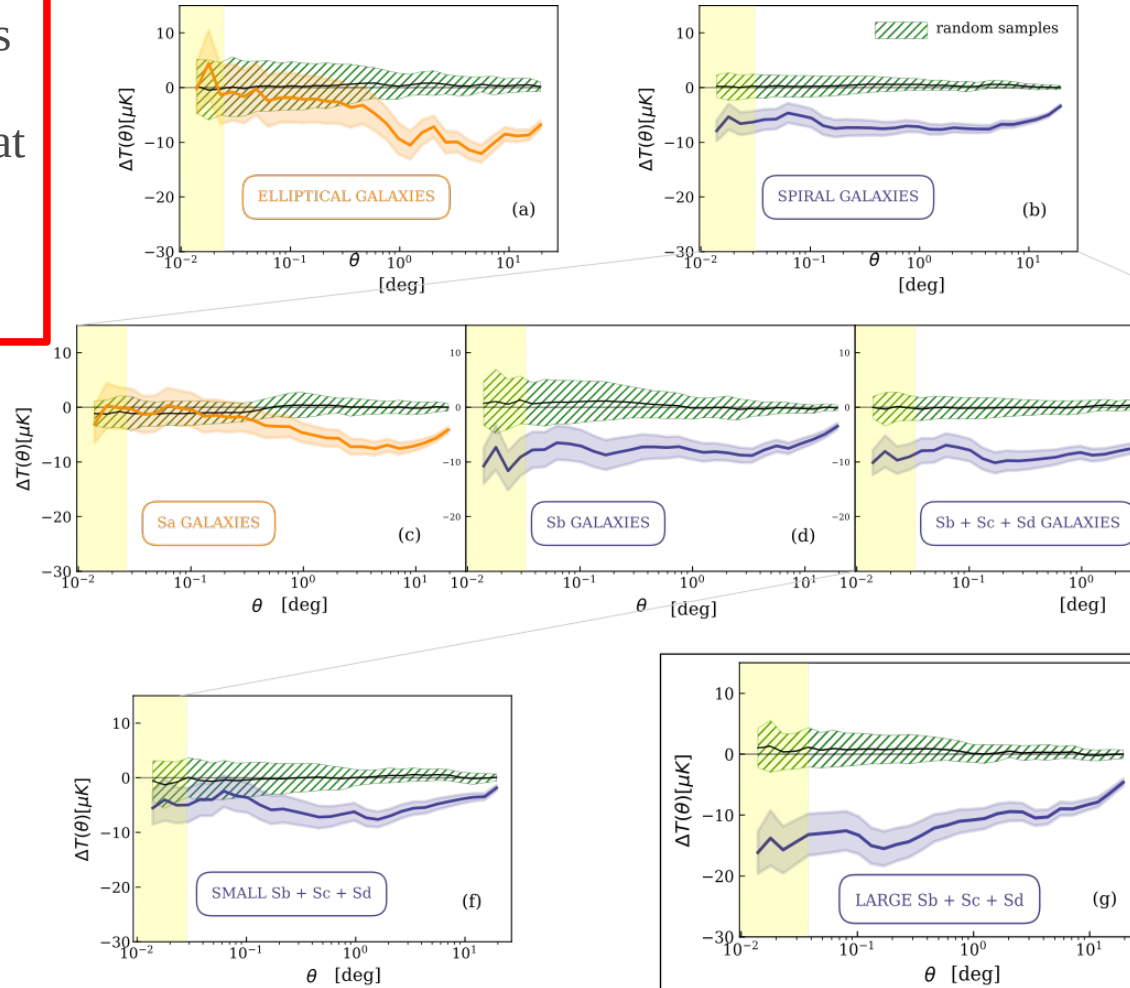
Elliptical galaxies only differ from random samples at large distances from the galaxy centres

the observed signal is arising from the late type Spiral galaxies

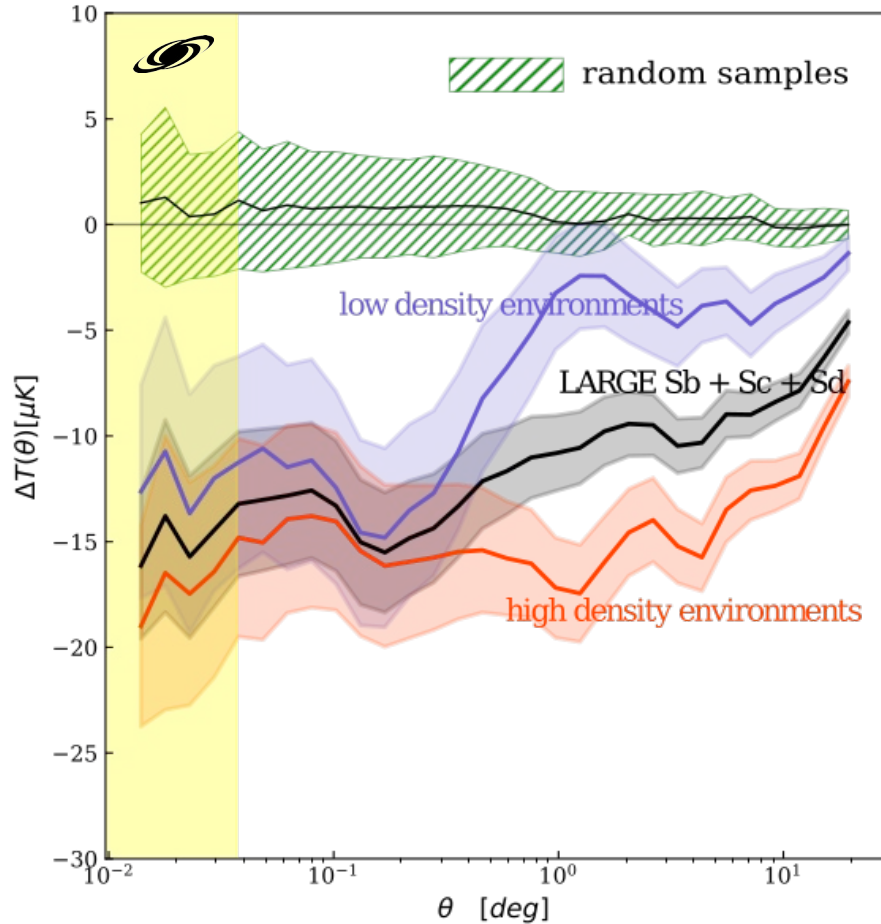
Spiral galaxies have a significant signal decrement

the observed decrement is due to the presence of large late type Spiral galaxies

Slow convergence for all the samples (..?)



## Temperature profile for the galaxy samples according to the local environment



at small angular separations the environmental effect is almost negligible, while at large separations the environment does play a significant role in the scale of convergence of the signal

## Simple model of the effects

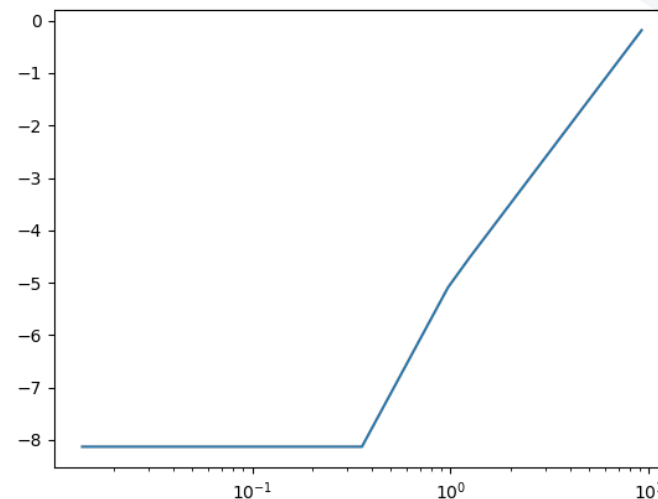
- \* statistically significant CMB temperature decrements of  $\sim -15\mu\text{K}$  around nearby galaxies
- \* effect largely dominated by large late type Spiral galaxies (Sb + Sc + Sd)
- \* isolated large late type galaxies are less affected by clustering effects

The systematic large scale effects of both elliptical and small late type spiral galaxies could be imprinted by those associated **only to large late type Spiral galaxies** via clustering

We propose a simple model that **only considers the results of isolated large late types to do the fit**

## Simple model of the effects

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



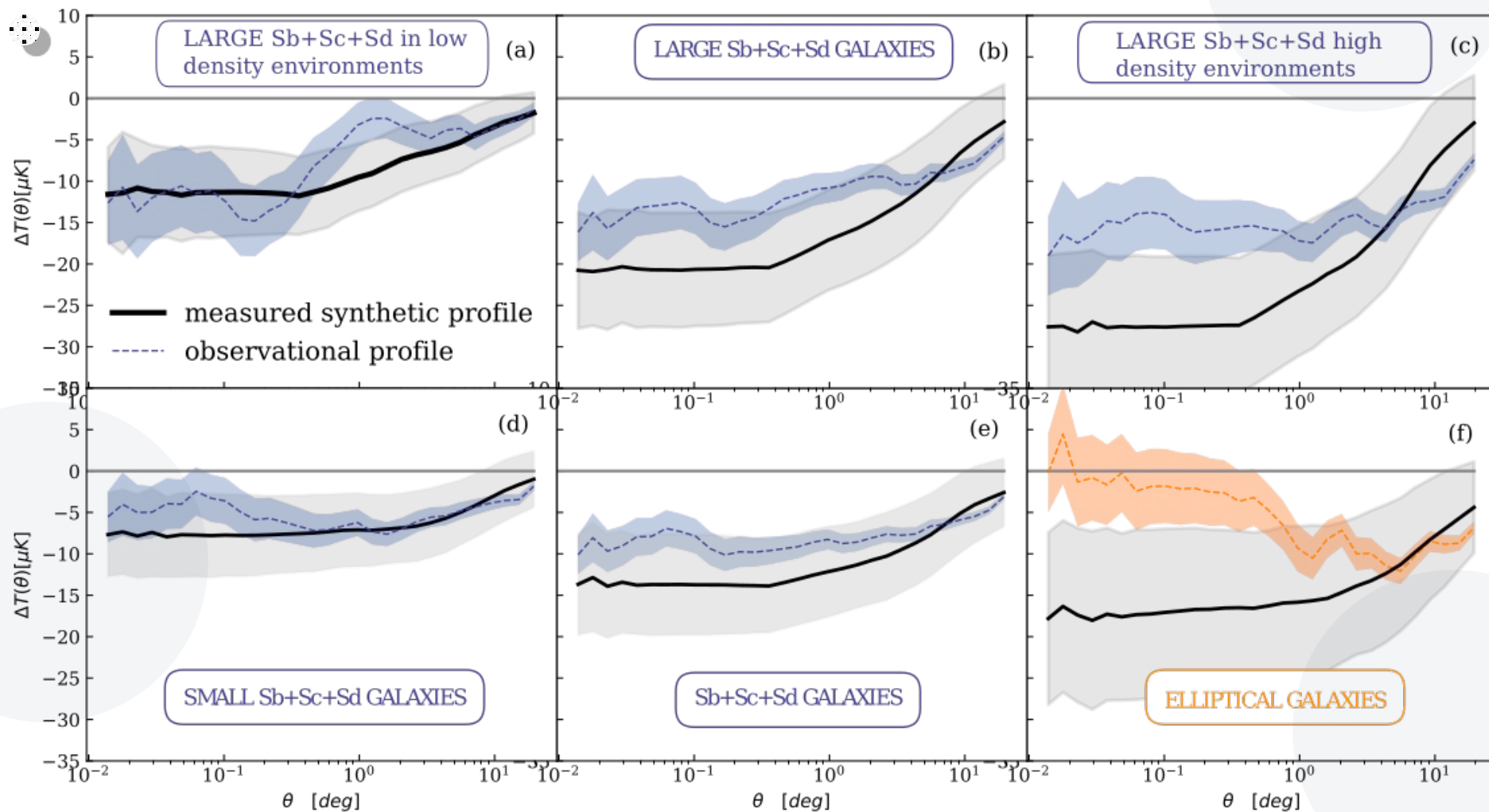
A suite of synthetic CMB maps consistent with the Planck spectrum results are used as background maps

The profile is imposed over all the large late type Spiral galaxies only

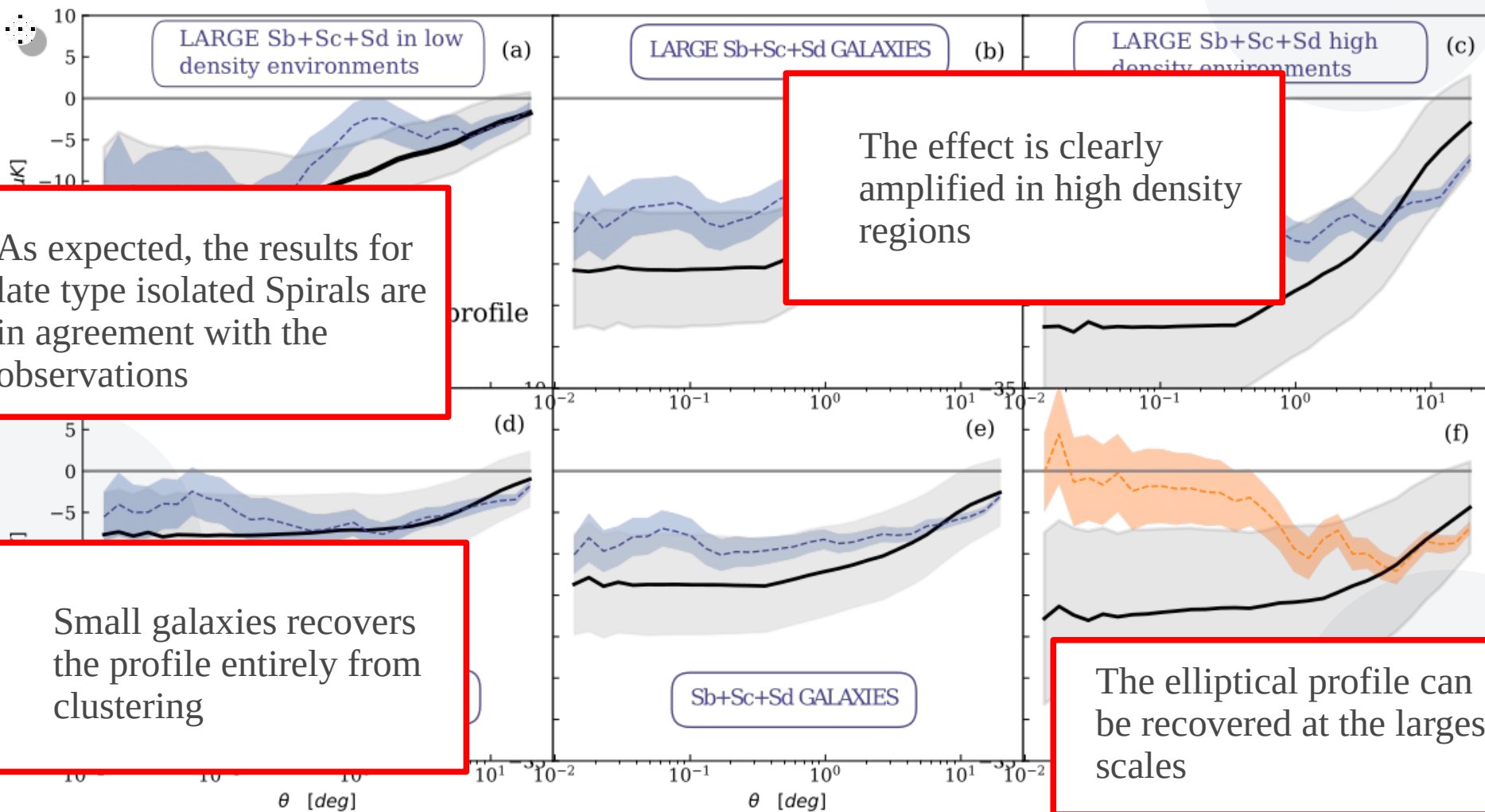
The clustering properties of each sample are the same as in the real data



## Simple model of the effects

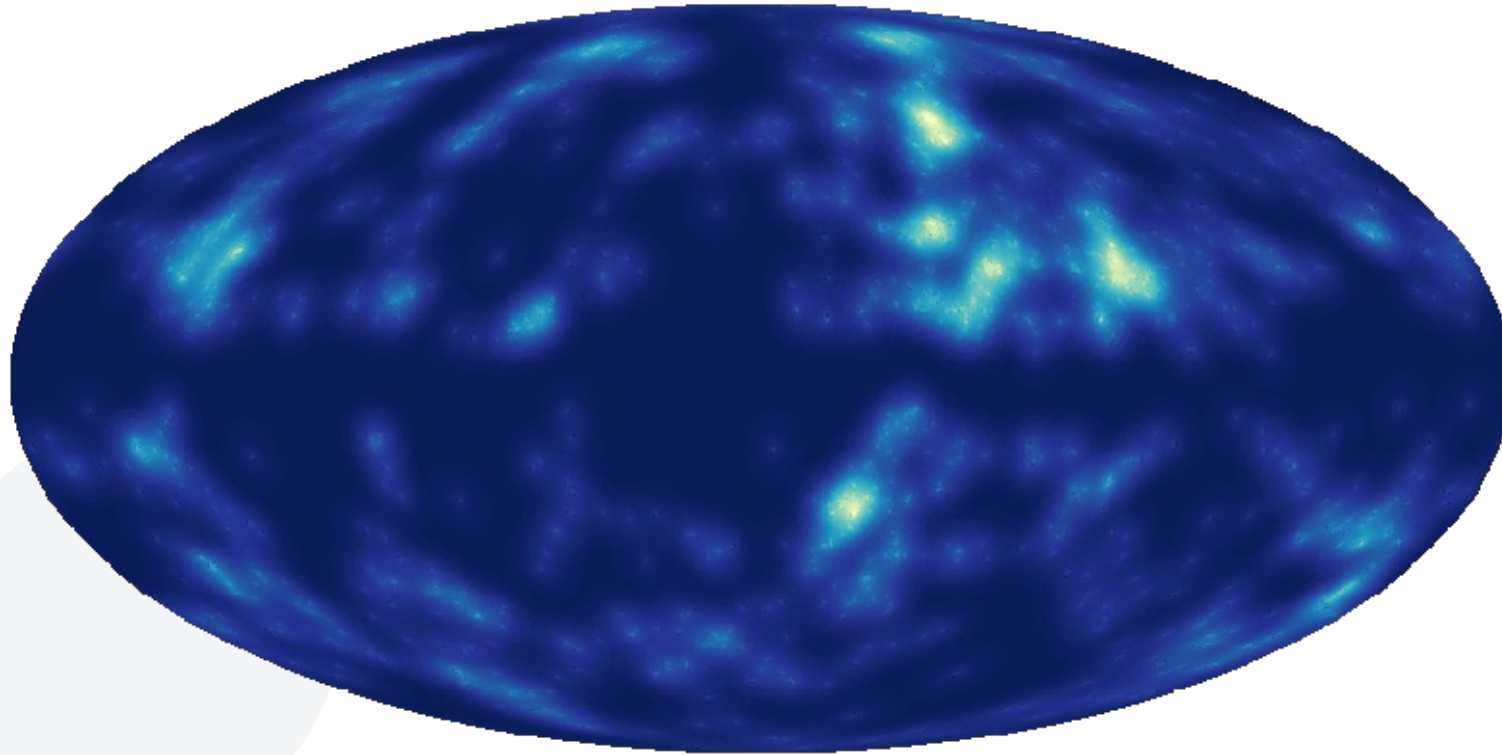


## Simple model of the effects



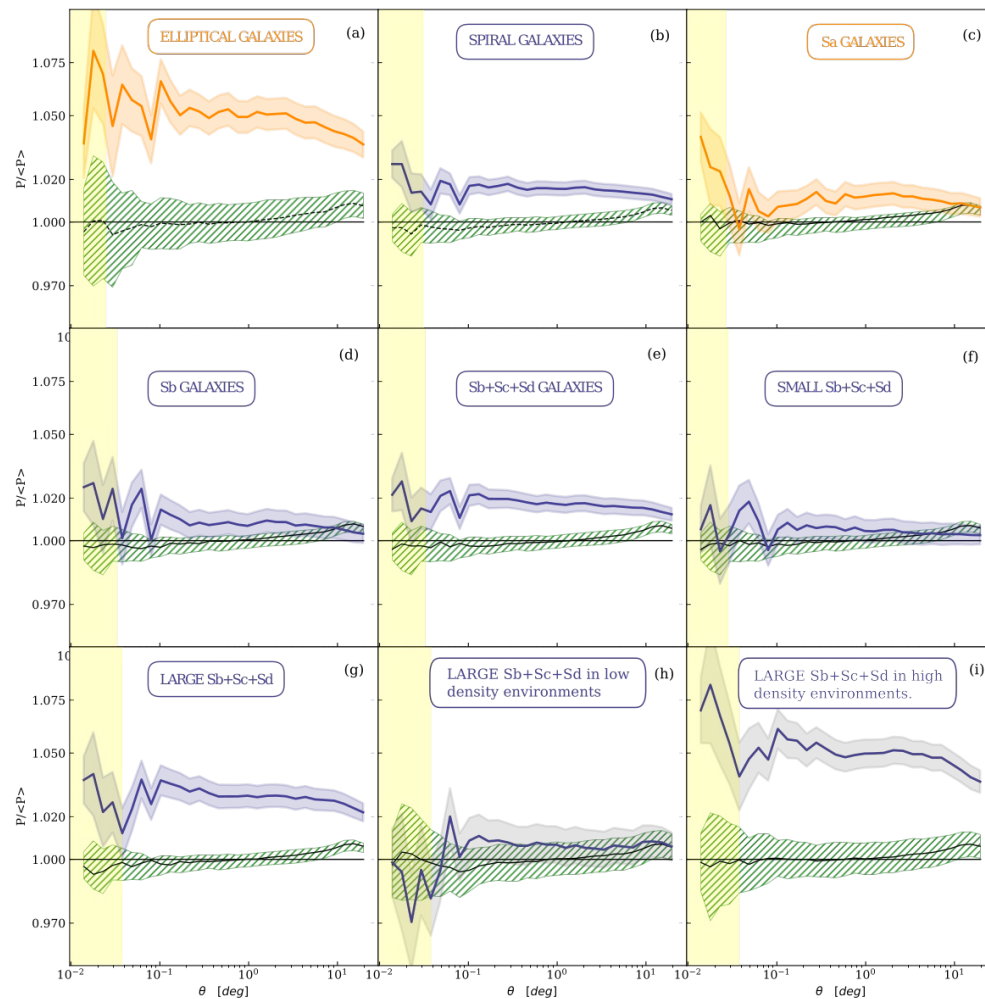
## Simple model of the effects

Sinthetic model profile for large Sb + Sc + Sd galaxies

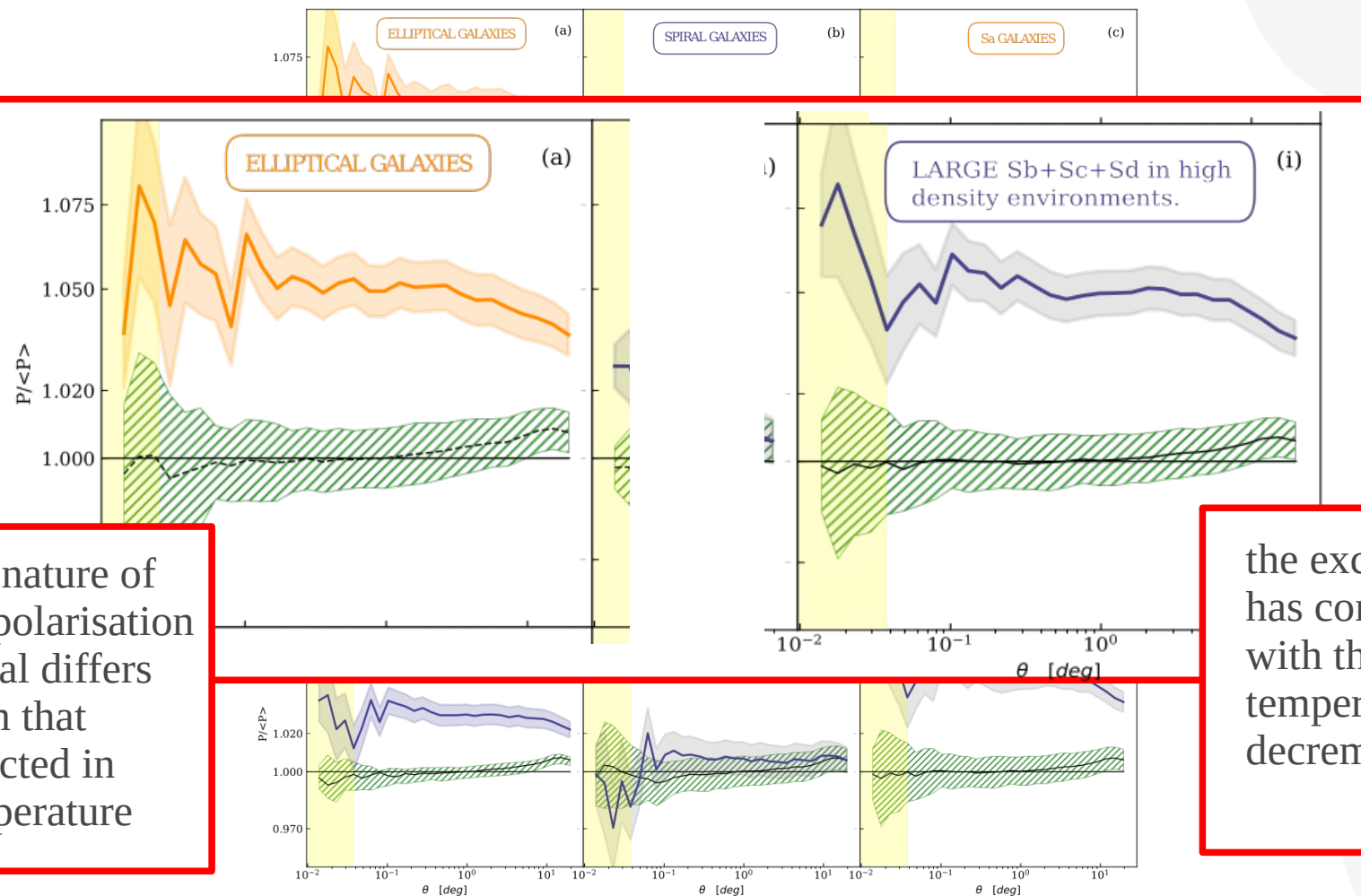


model the effects by its association only to large late type Spiral galaxies is a reasonable approximation to explain the origin of the observed signal

## Polarisation flux profile for the galaxy samples



## Polarisation flux profile for the galaxy samples

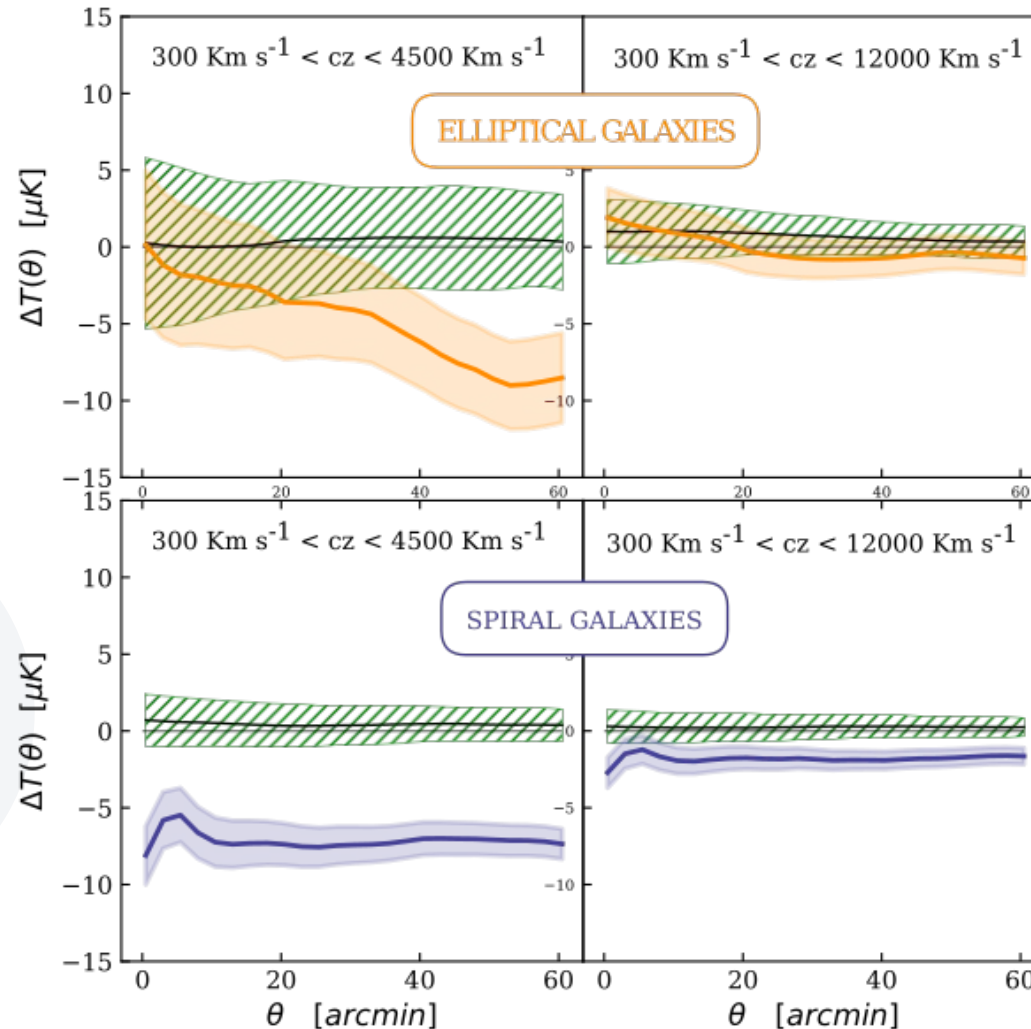


the nature of the polarisation signal differs from that detected in temperature

the excess of flux has correspondence with the strongest temperature decrements

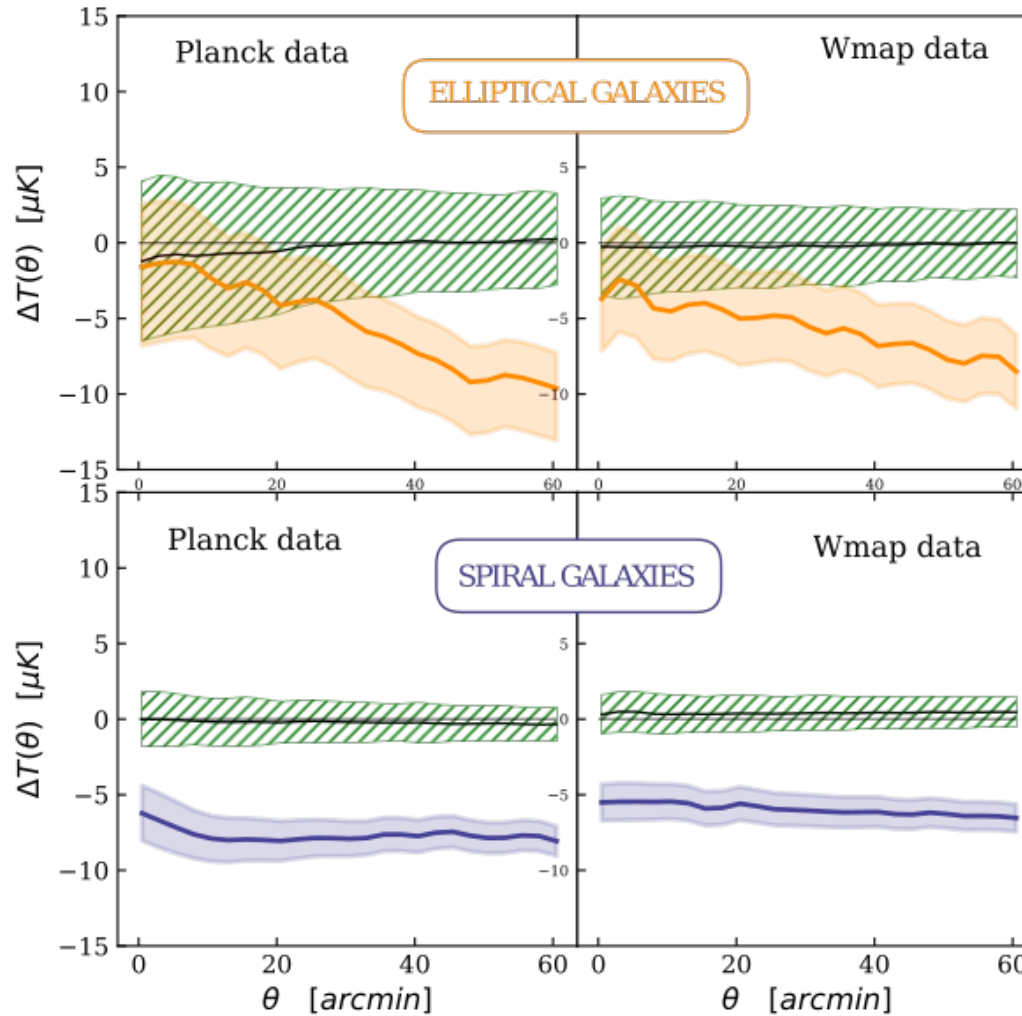


## Redshift dependence



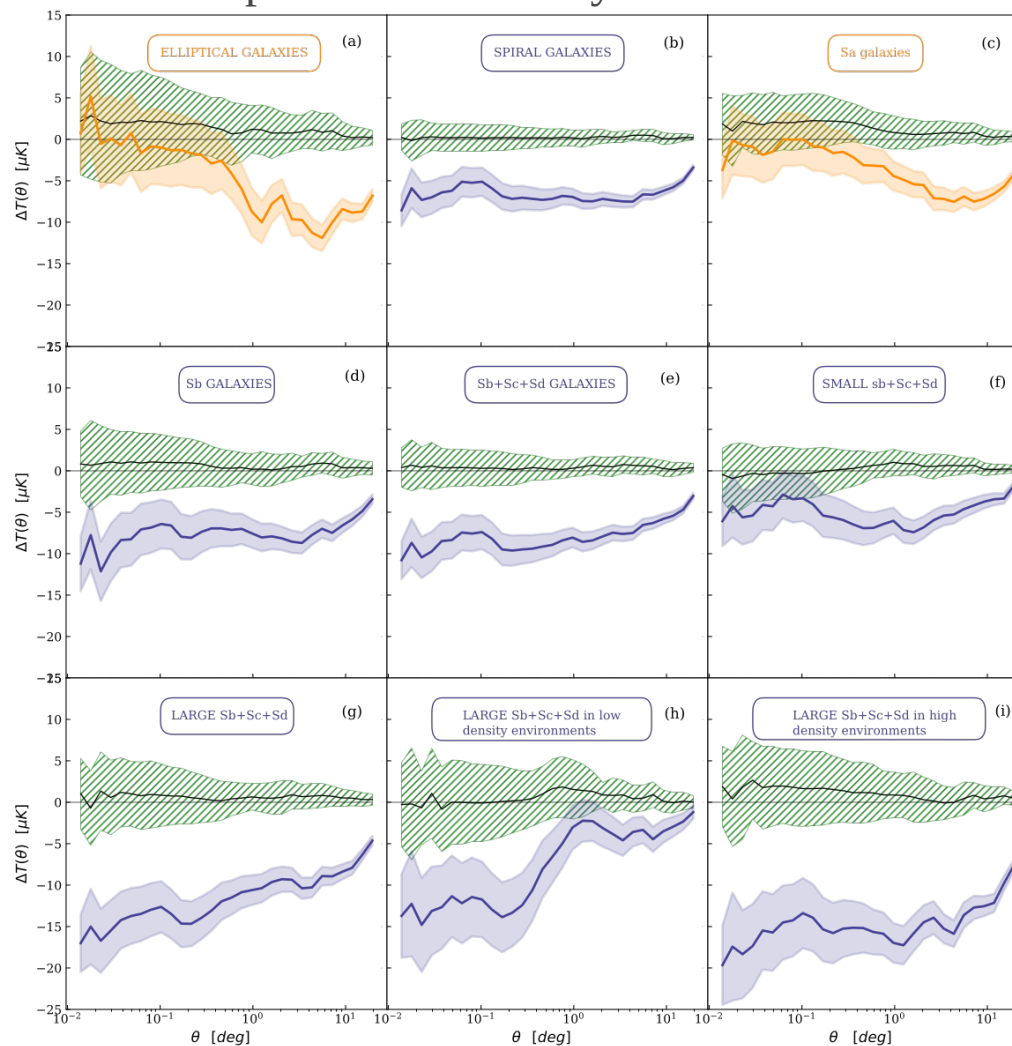
The signal almost vanishes for more distant galaxies. This reinforces the hypothesis that the foreground effect is due to nearby Spiral galaxies

## Confirmation with WMAP data



WMAP data allow us to recover the signal previously found in Planck data

Temperature profiles using SMICA map from which Sunyaev-Zeldovich sources have been projected out



the SZ effect  
is not a  
significant  
driver of the  
results

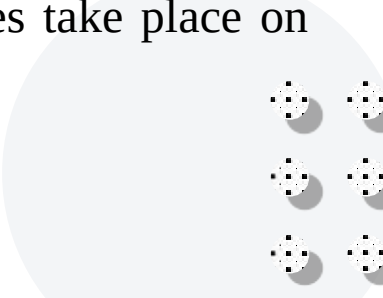
## SUMMARY

Nearby Spiral galaxies ( $cz < 4500$  km/s) are associated to statistically significant CMB temperature decrements ( $\sim -15$  microK) that extend to several galaxy radii.

The effect is found using the Planck temperature map and is also well reproduced in the final release of the WMAP sky map.

**Although there are several known sources of foregrounds that are removed at high confidence level through the pipelines, our findings suggest that some sources of contamination from the nearby universe are still present in the CMB data.**

Overall, the presence of foregrounds associated with the galaxy samples analysed here, together with the features extracted from the measured signal, suggest that astrophysical processes take place on large intergalactic scales.



Muito obrigado!!!