A Giant in the Cosmic Web

A Galactic Superstructure of ~700 Mpc Scale

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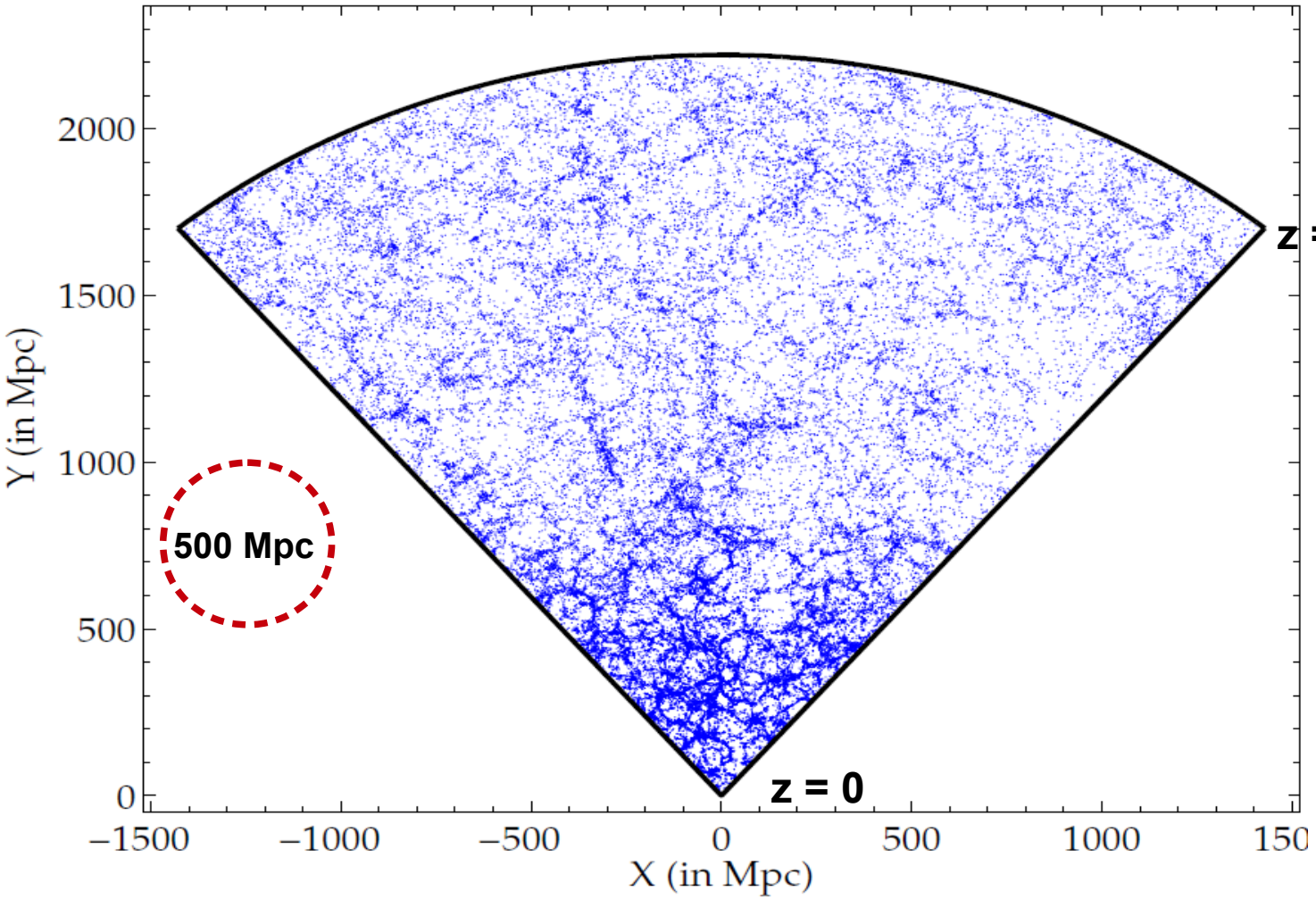
Undiscovered "Giants" in the cosmic web?



Comoving Cords.

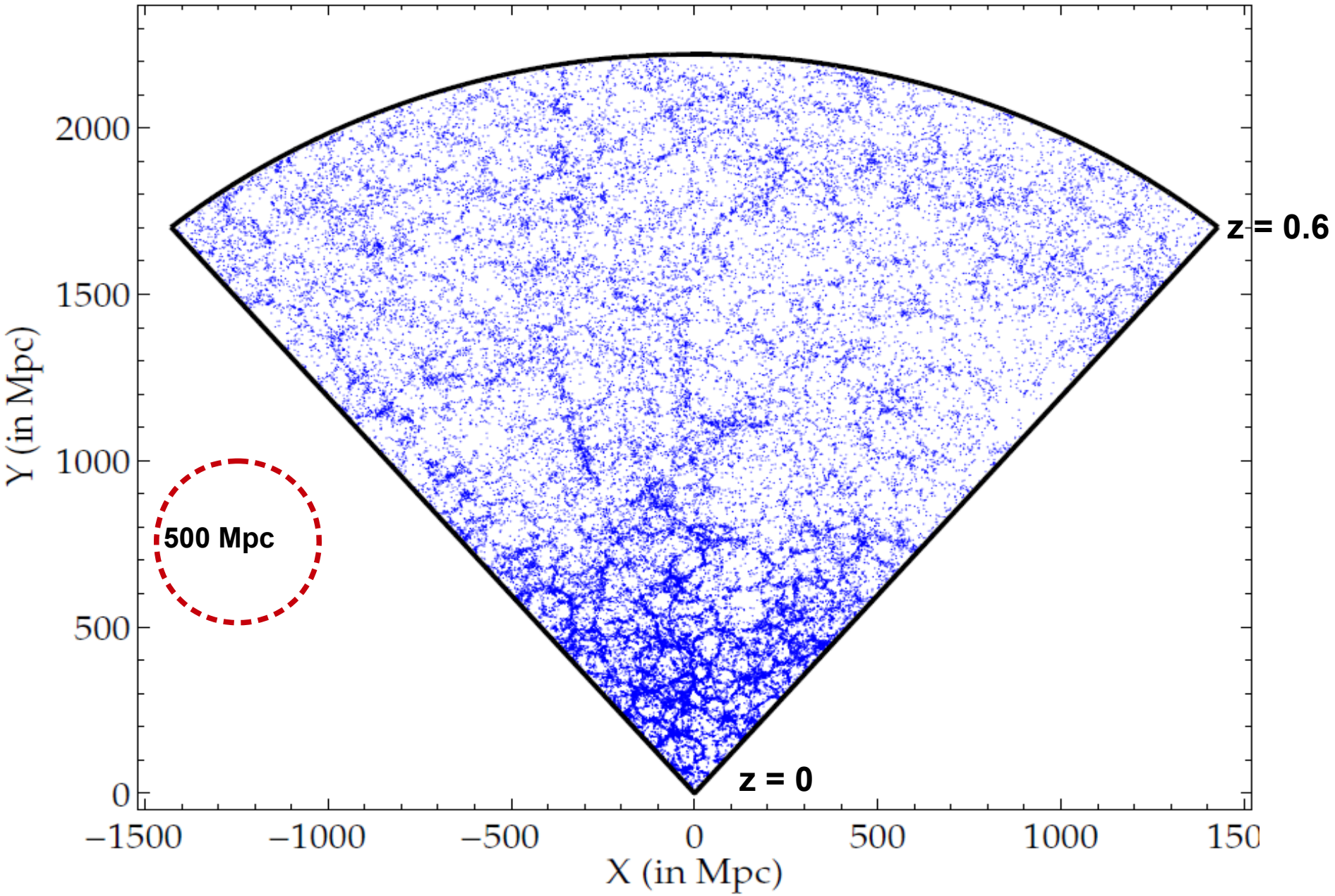
Redshift range

z = 0 – 0.6 shown

We show a very large ~200 Sq. Degree area from the SDSS-III Survey

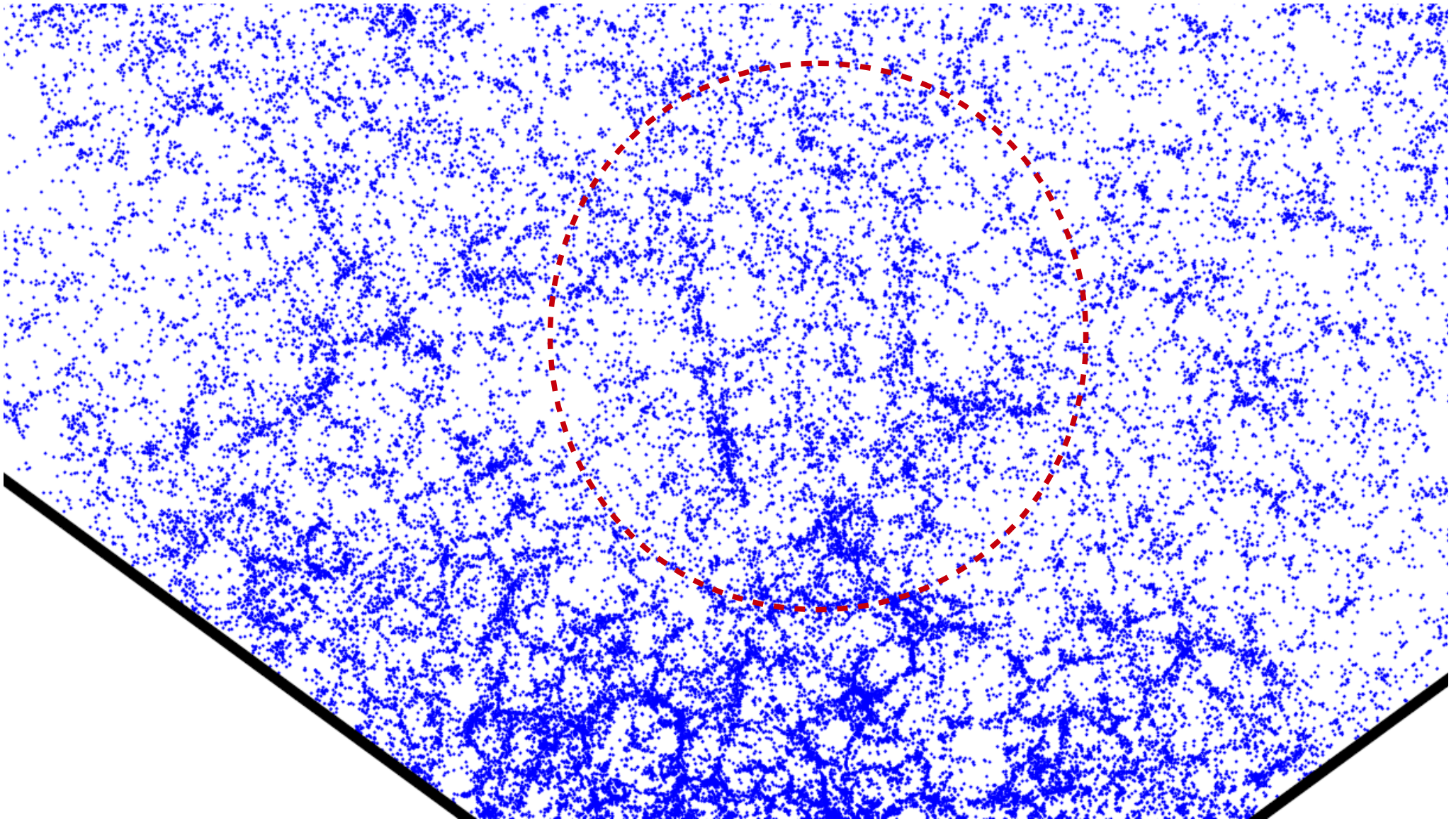
All galaxies in this redshift cone have accurate spectroscopic redshifts

One can easily spot two very large -scale galactic superstructures of ≥ 500 Mpc scale !


2000
1500
1000
500
0
Y (in Mpc)
−1500
−1000
−500
0
500
1000
150
X (in Mpc)
500 Mpc
z = 0.6
z = 0

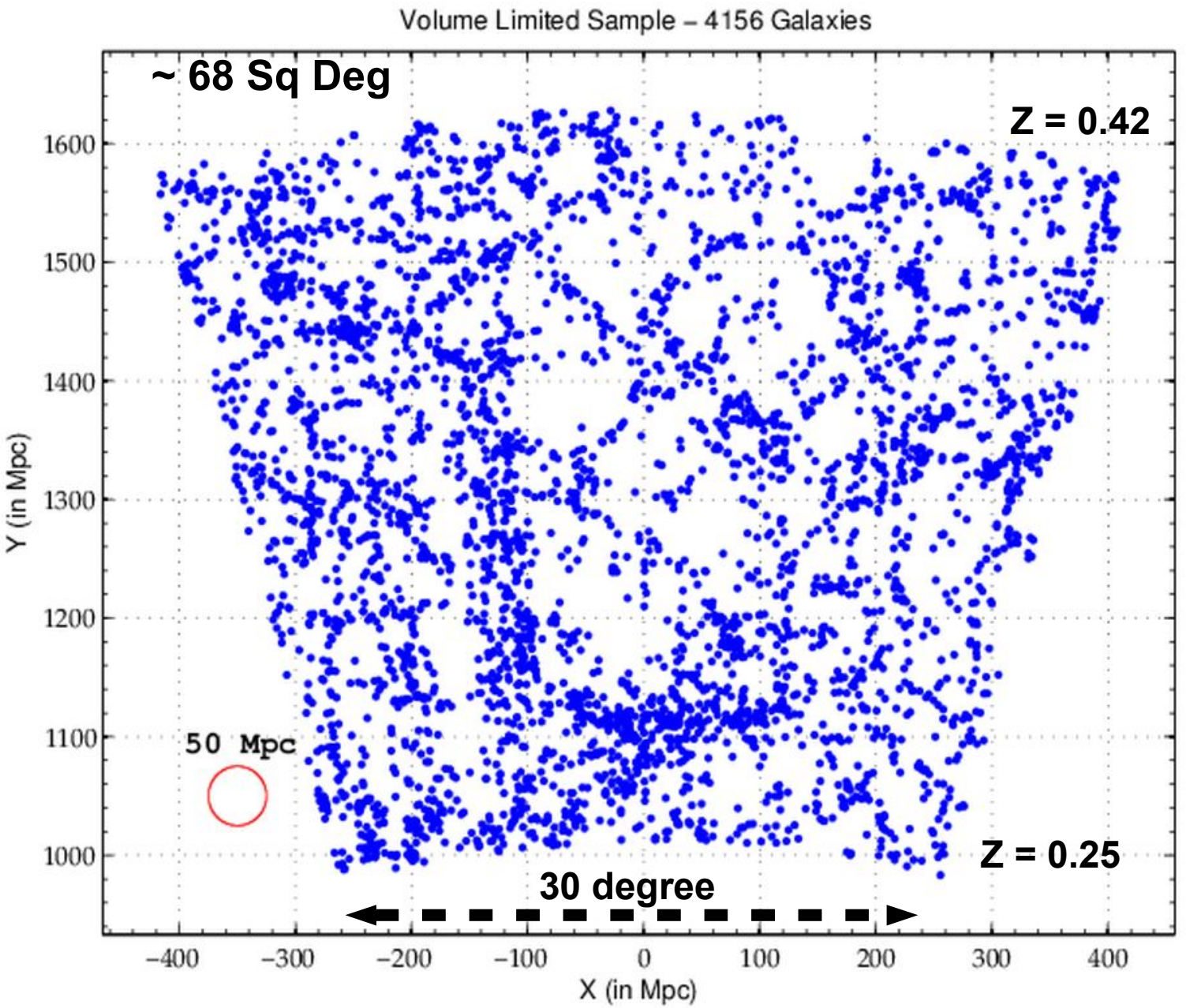
Zoom on the cosmic-web containing the super-structure(s)

Circle diameter is ~ 750 Mpc comoving !



No! This can not be a fingers-of-God effect

The Largest Supercluster !



Volume limited sample shown

Total ~ 4200 galaxies

About 1000 galaxies trace the large S-shaped filament

End-to-end "span" 650 – 700 Mpc!

Network of huge voids, filaments on the right

Chain of voids on left (A void pipe/ tunnel ?)

Identifying and Characterizing the new super-structure

We have used two independent methods for an objective analysis :

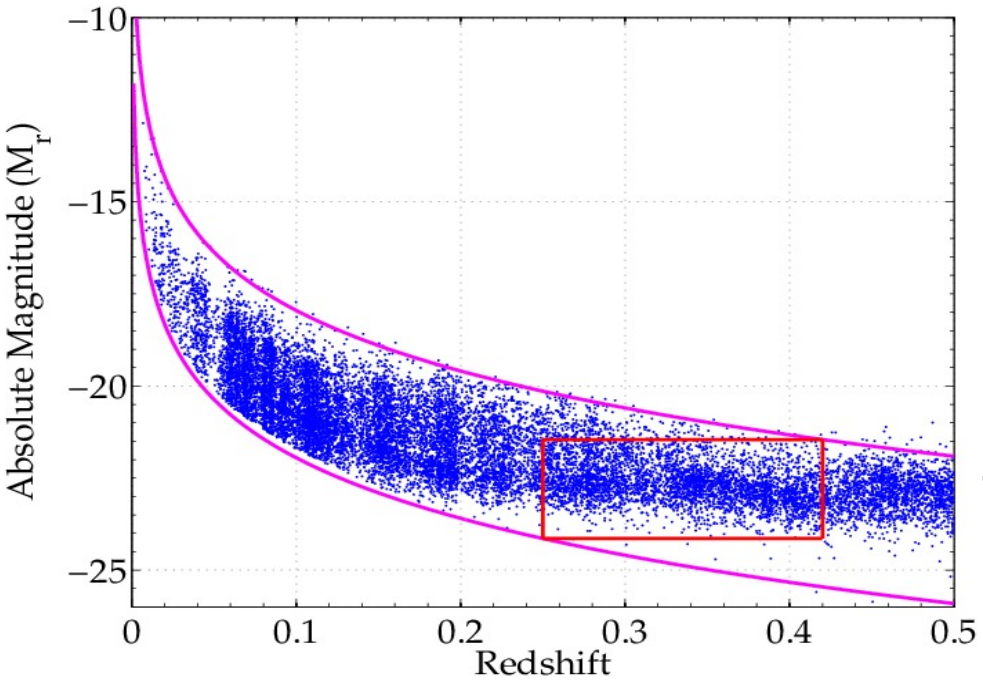
1. **Smoothed density field method + the "ShapeFinder" mathematical analysis tool**

(Sahni, Satyaparakash & Shandarin 1998)

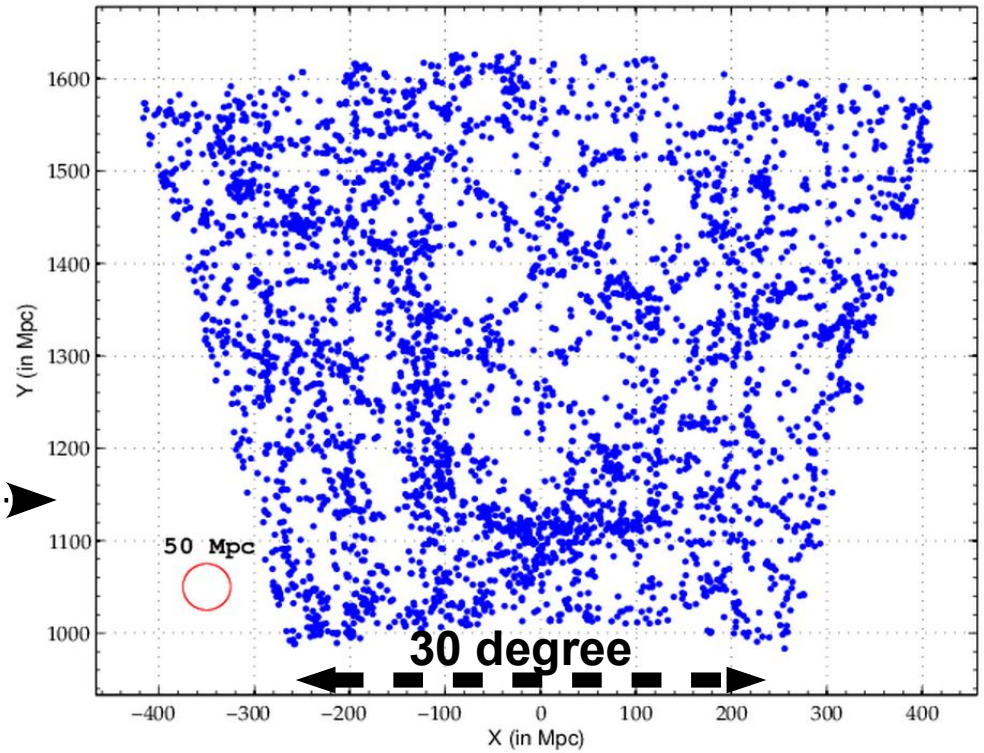
2. **The Voronoi/Delaunay tessellation method**

(See the poster by Shishir Sankhyayan)

Forming a volume limited sample



Volume limited sample: 4156 galaxies



Redshift and magnitude cuts

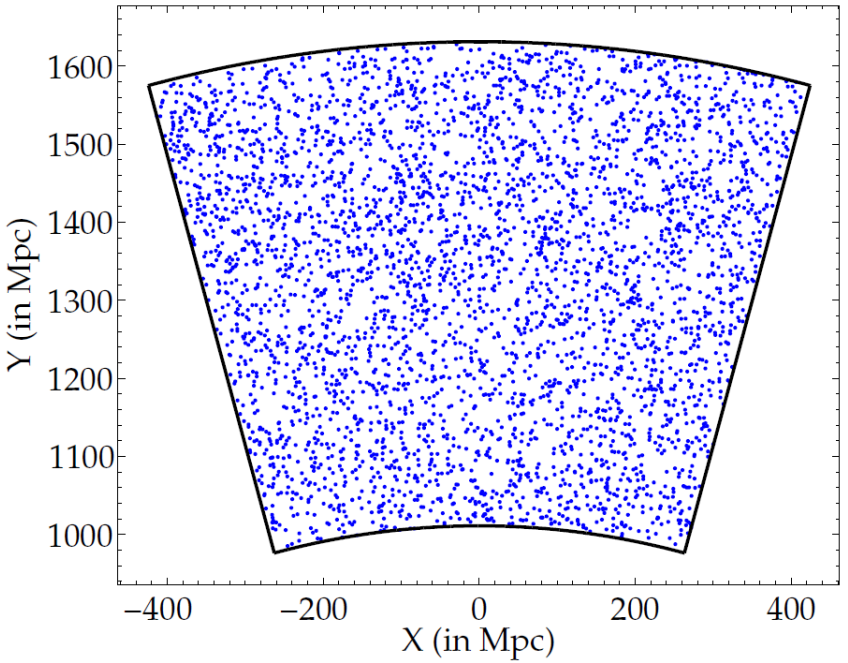
0.25 < z < 0.42

k- corrected r magnitude

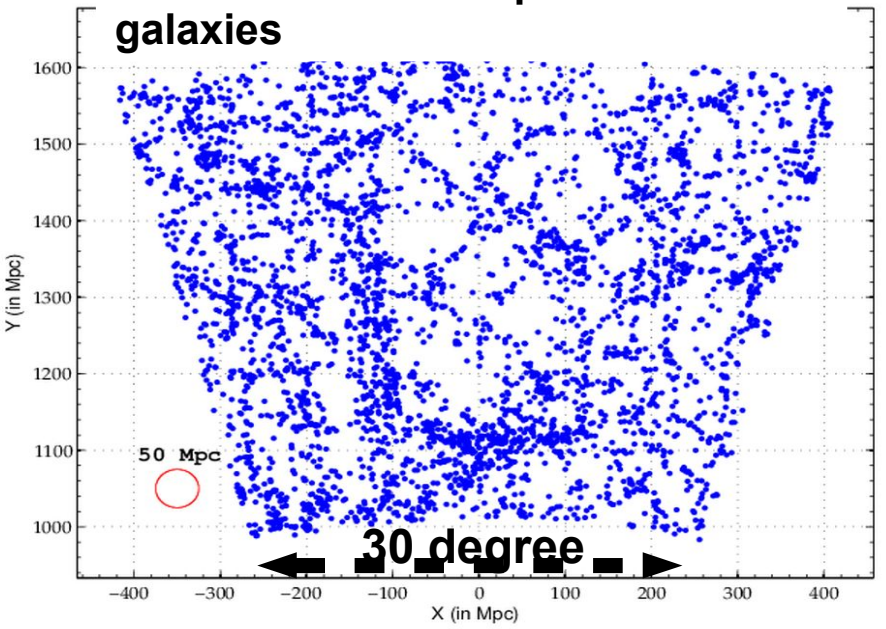
- 21.18 > M(r) > - 25.1

Comparison with random catalogs

A random catalog



Volume limited sample: 4156 galaxies



Generate random point sets having the same number density and the same angular coverage on the sky as the observed galaxy subsample

Obtain a number of random mock samples and in them find clustering of points in the same way as for the real sample

Compare using rigorous statistical tests like Kolmogorov – Smirnov test

Null hypothesis is rejected at high (> 95%) significance

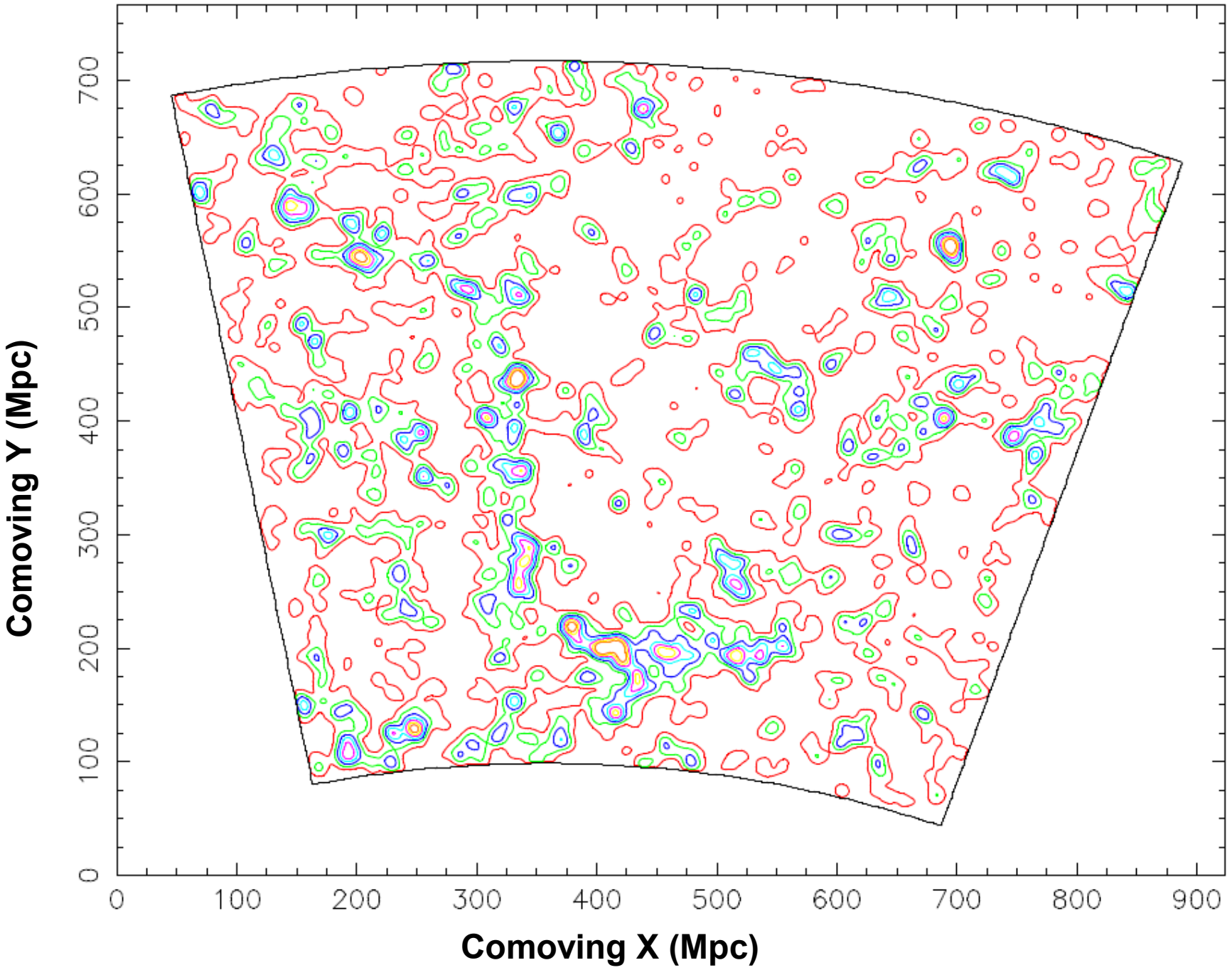
Methodology: Smoothed Density Field

- Galaxy distribution mapped to a grid spacing 1 Mpc using Cloud-in-Cell (CIC) method
- Smoothed density field was constructed by smoothing with Gaussian kernal with smoothing length $L \sim 5$ Mpc

Smoothing scale 1/2 of the mean intergalactic separation $\lambda \sim 10$ Mpc

We have a fairly good sampling. Avoid crossing the percolation threshold

Smoothed Density Field Contours



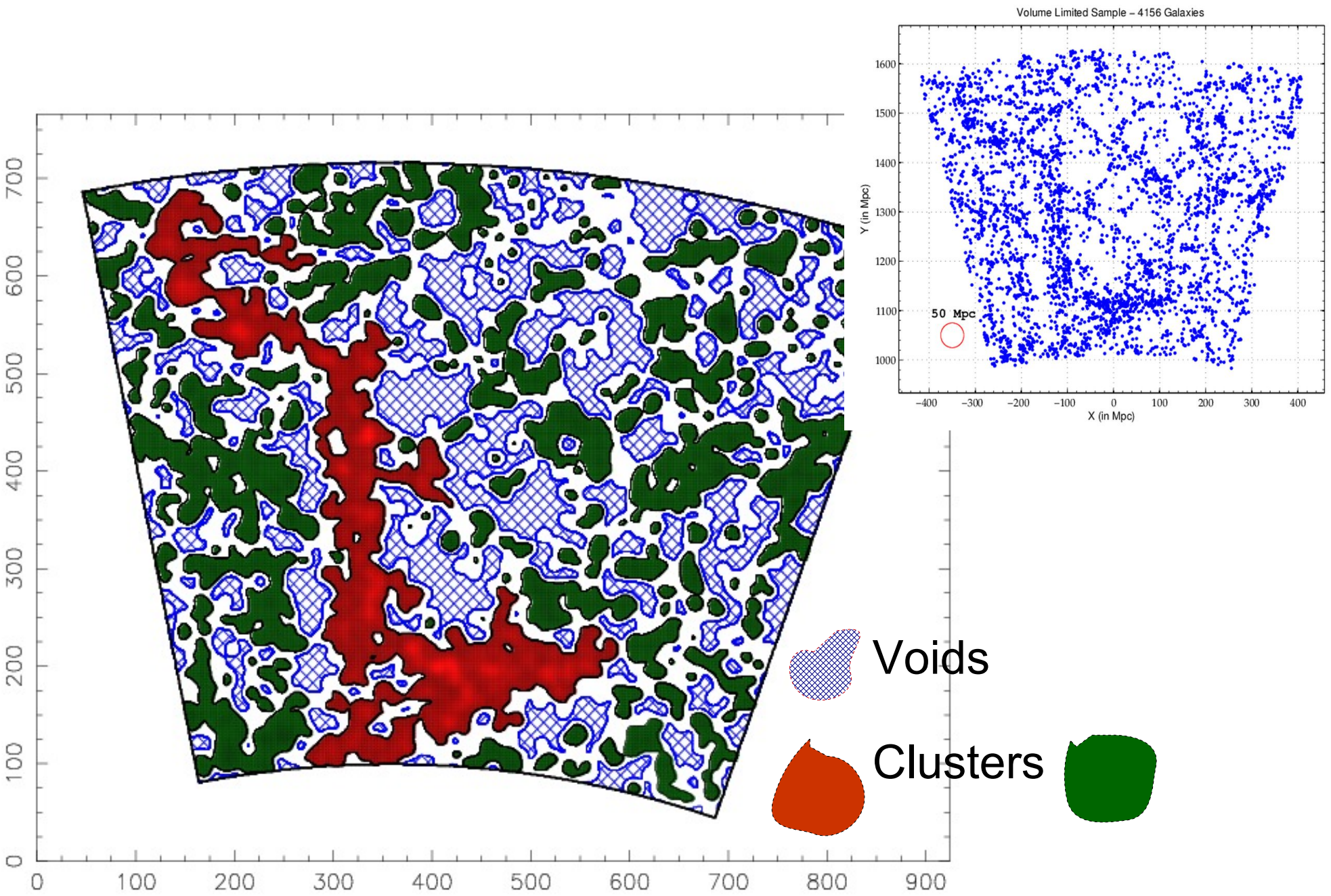
Identifying the overdensities and voids

We define overdense regions as $\rho > \rho_{(mean)}$

underdense (void) regions as $\rho \leq 0.2\ \rho_{(mean)}$

Friends-of-Friends (FOF) used to identify Interconnected "cluster" or "void" cells

Linking Length? Effectively LL = 5 Mpc,
about half of mean galaxy separation $\lambda \sim 10$ Mpc.
Thus, much below the percolation threshold


Volume Limited Sample – 4156 Galaxies
Y (in Mpc)
X (in Mpc)
50 Mpc
1600
1500
1400
1300
1200
1100
1000
−400
−300
−200
−100
0
100
200
300
400
0
100
200
300
400
500
600
700
800
900
Voids
Clusters

ShapeFinder diagnostic

Mecke et al. (1994)

In 2D the three Minkowski Functionals are:

1. Surface Area (S)
2. Perimeter (P)
3. Euler Characteristics (χ)

Sahni et al. (1998)

Filamentarity ($\mathcal{F}$)

$$\mathcal{F} = \frac{P^2 - 4\pi S}{P^2 + 4\pi S}, \qquad 0 \leq \mathcal{F} \leq 1$$

Filled Circle (R): $S = \pi R^2,\ P = 2\pi R \Rightarrow \mathcal{F} = 0$

Line (L) : $S = 0,\ P = 2L \Rightarrow \mathcal{F} = 1$

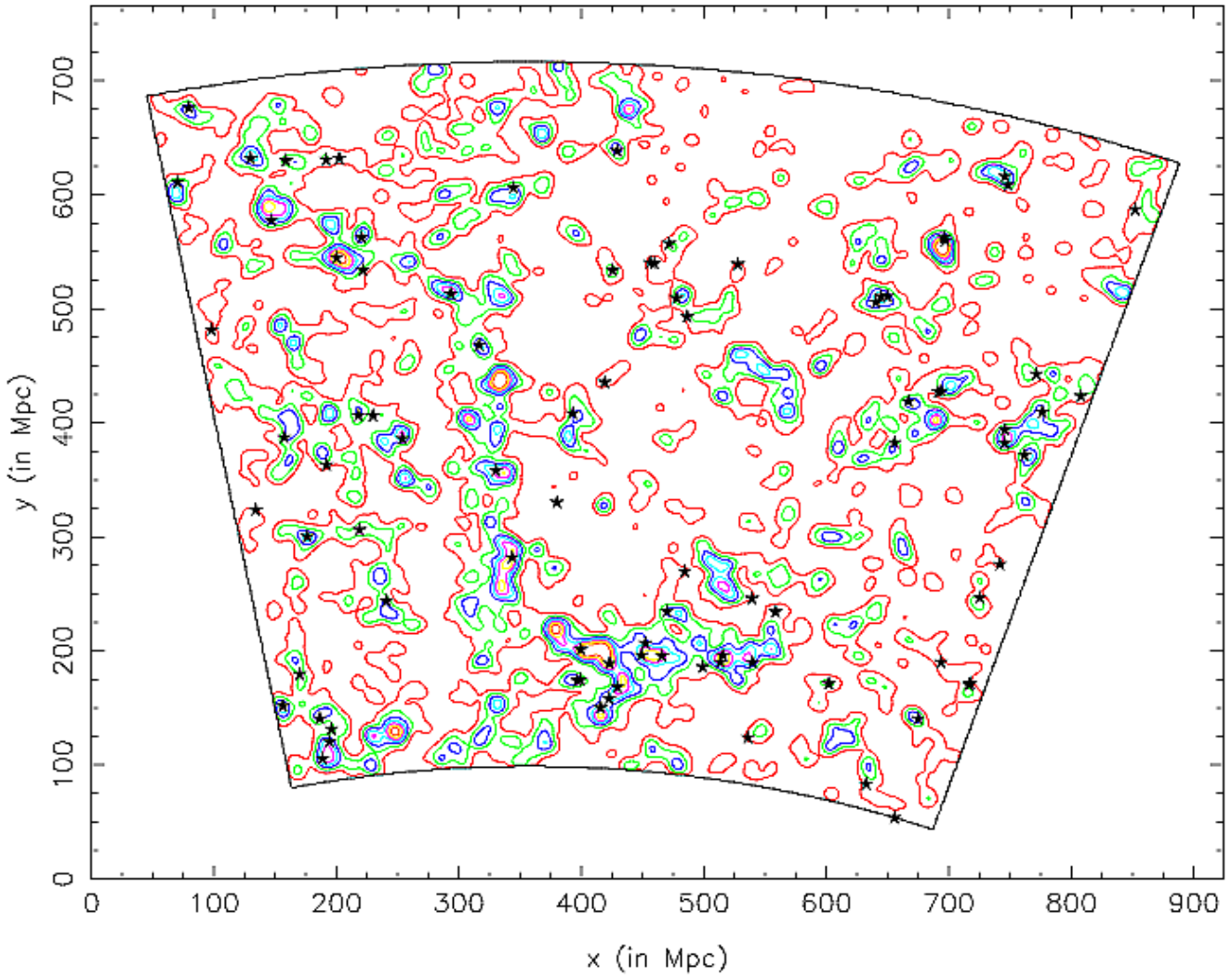
For a highly filamentary Object F ≈ 1

ShapeFinder diagnostic (result)

Minkowski Functionals and Filamentarity for the 5 largest high density clusters

Structure no	Area ($\times 10^3 Mpc^2$)	Perimeter ($\times 10^2 Mpc$)	Euler Characteristics	Filamentarity
1	52.2	45.7	−8	0.94
2	14.9	16.7	−1	0.87
3	6.62	7.45	1	0.74
4	6.23	7.27	−1	0.74
5	5.65	6.65	0	0.73

Correlation with known galaxy clusters/groups

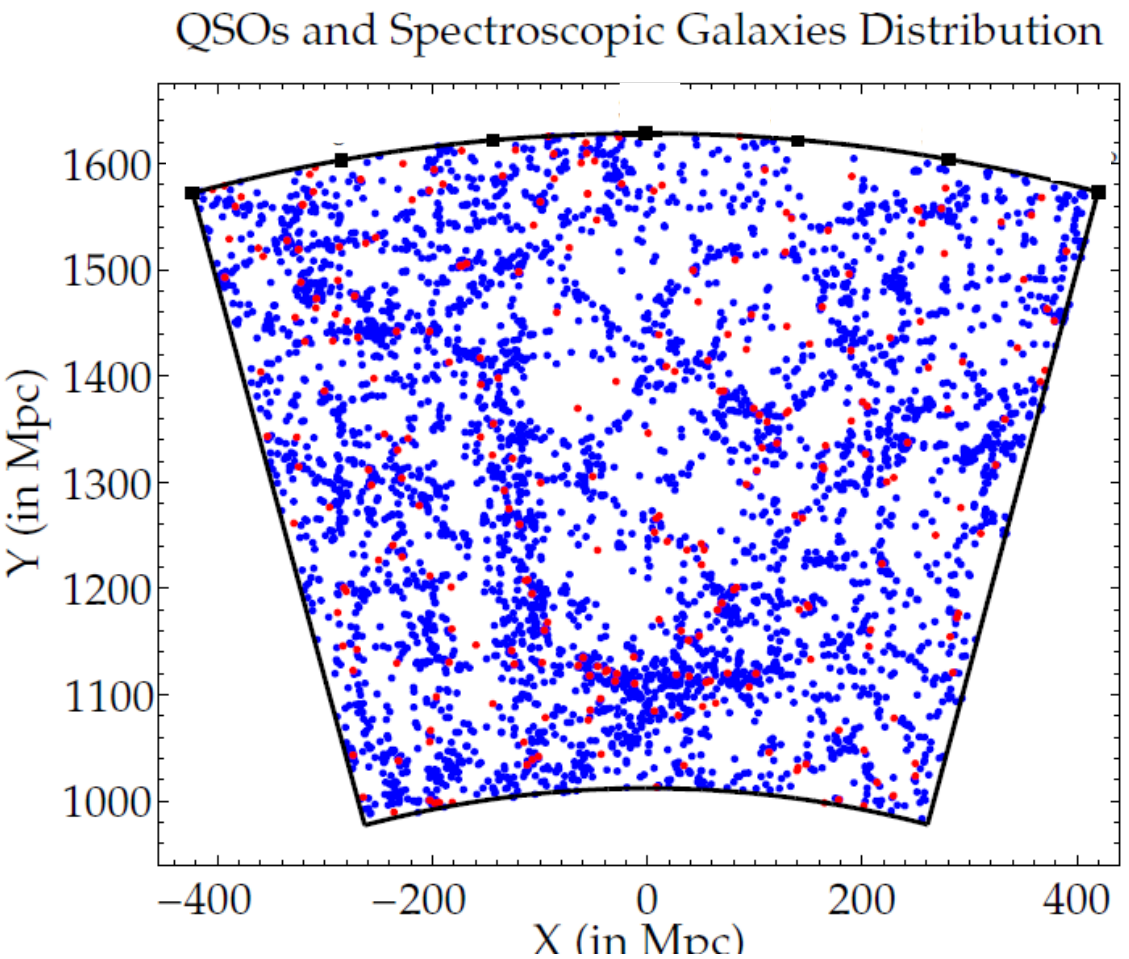


Almost 100% correlation with known clusters/groups In SDSS

GMBCG catalog

Hao et al., ApJS (2010)

Correlation with known quasars

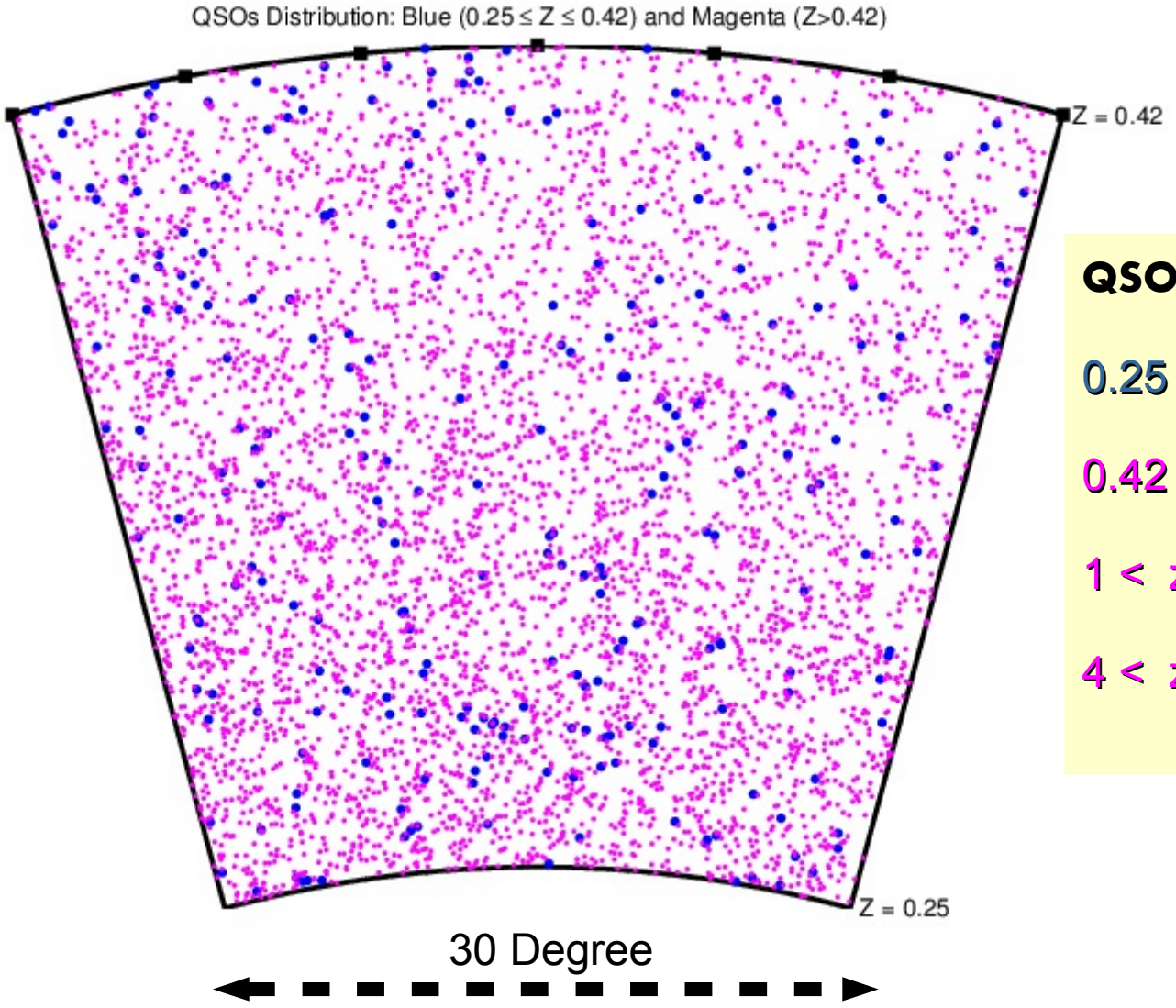


The known Quasars also closely trace the large-scale super cluster of galaxies

QSO Distribution (Total ~5500)

0.25 < z < 0.42	**273 (shown)**
0.42 < z < 1	**1,115**
1 < z < 4	**4,136**
4 < z < 7	**51**

Distribution of QSOs in the region of supercluster



QSO Distribution (Total ~ 5,500)

0.25 < z < 0.42	273
0.42 < z < 1	1,115
1 < z < 4	4,136
4 < z < 7	51

1. A giant galaxy supercluster on a very large scale is found from SDSS-III deep spectroscopic sample (largest spanning size ~ 600 – 700 Mpc)

2. Highly filamentary morphology surrounded by numerous voids and filaments

3. Strong correlation with known clusters/groups and quasars listed in SDSS

How such a very massive galactic structure originated ?

How many more may exist in the local/distant Universe?

Do we find such objects in the big numerical simulations?

Our discovery provides a direction for many future Observational and Theoretical studies.

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