

## Large Scale Structure in the Distribution of Galaxies



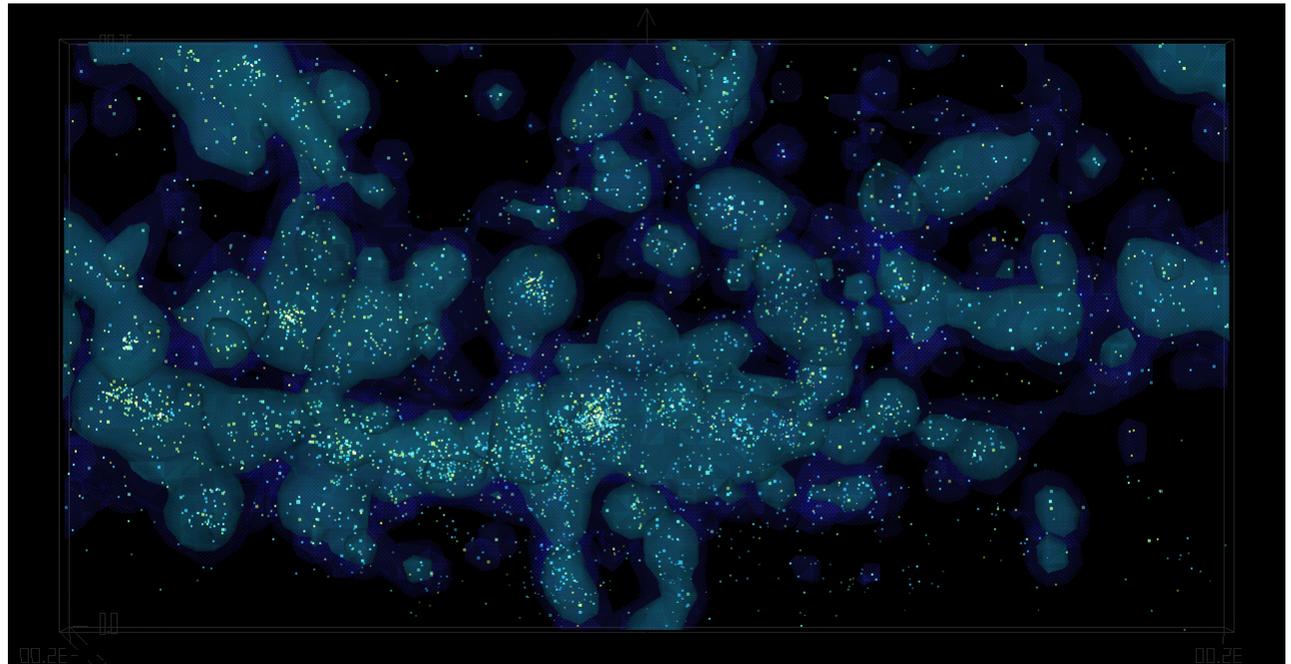
- Galaxies are the building blocks of structure on scales of tens of millions of light years
- Our nearest big neighbor is Andromeda galaxy, M31, at a distance of 2 million light years

# Galaxies Are Not Randomly Distributed

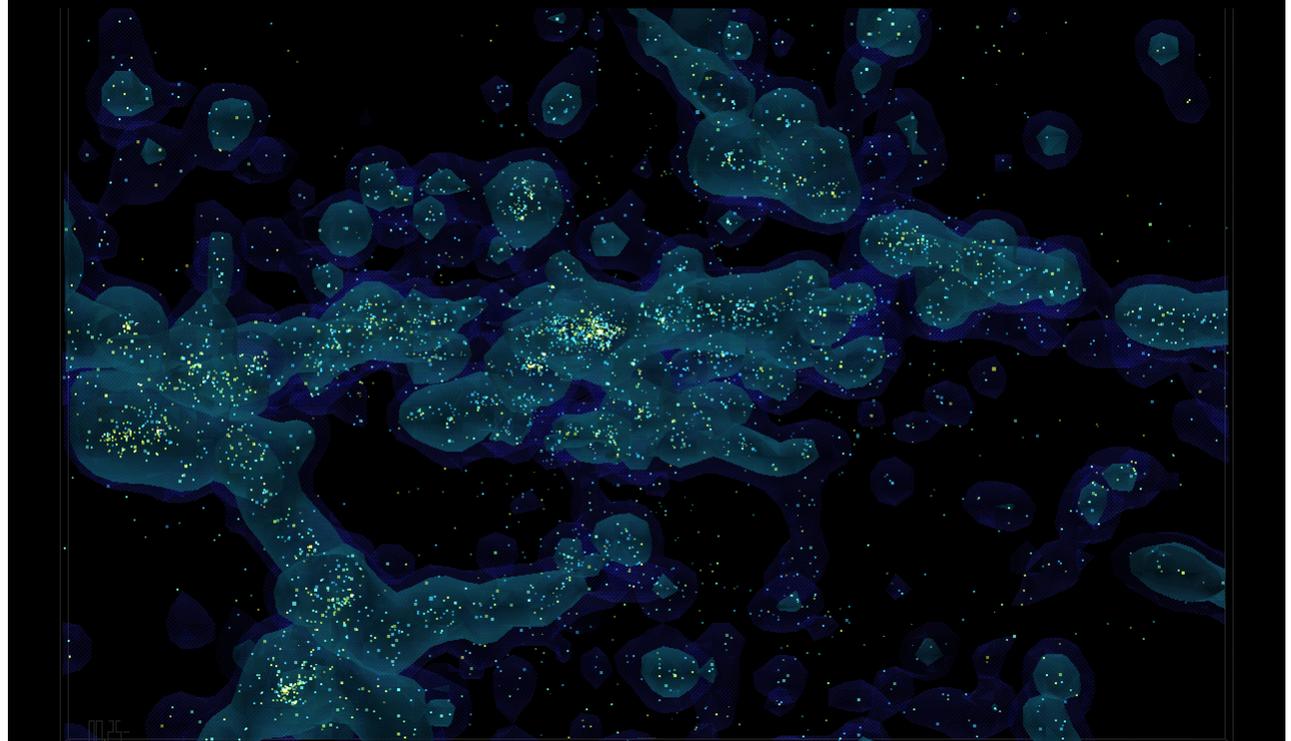
- They are organized into great networks
- Filaments
- Knots along the filaments called groups
- Big knots where filaments meet called clusters
- Big **empty** areas: **voids**

# Local Supercluster

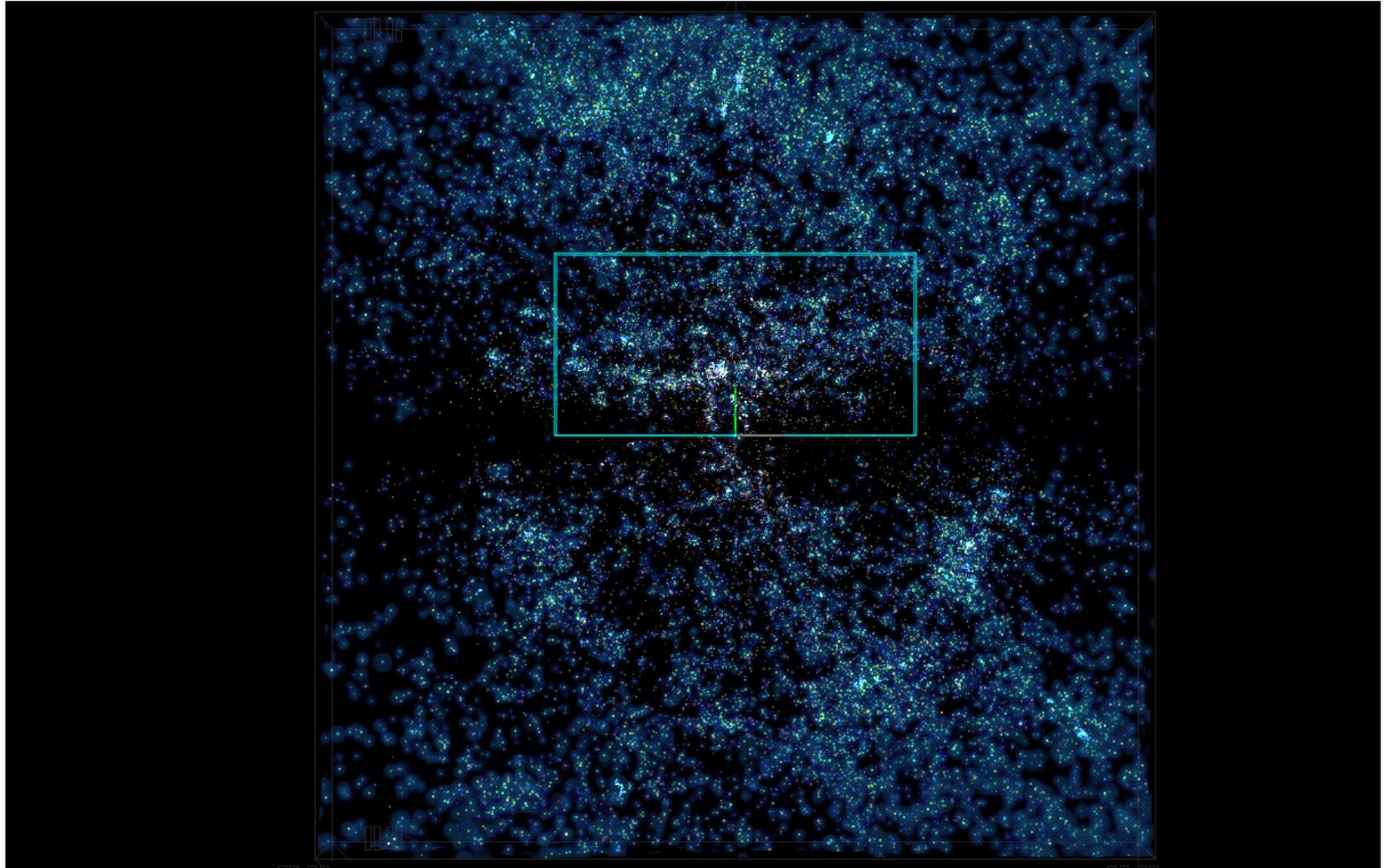
top view →



edge view →

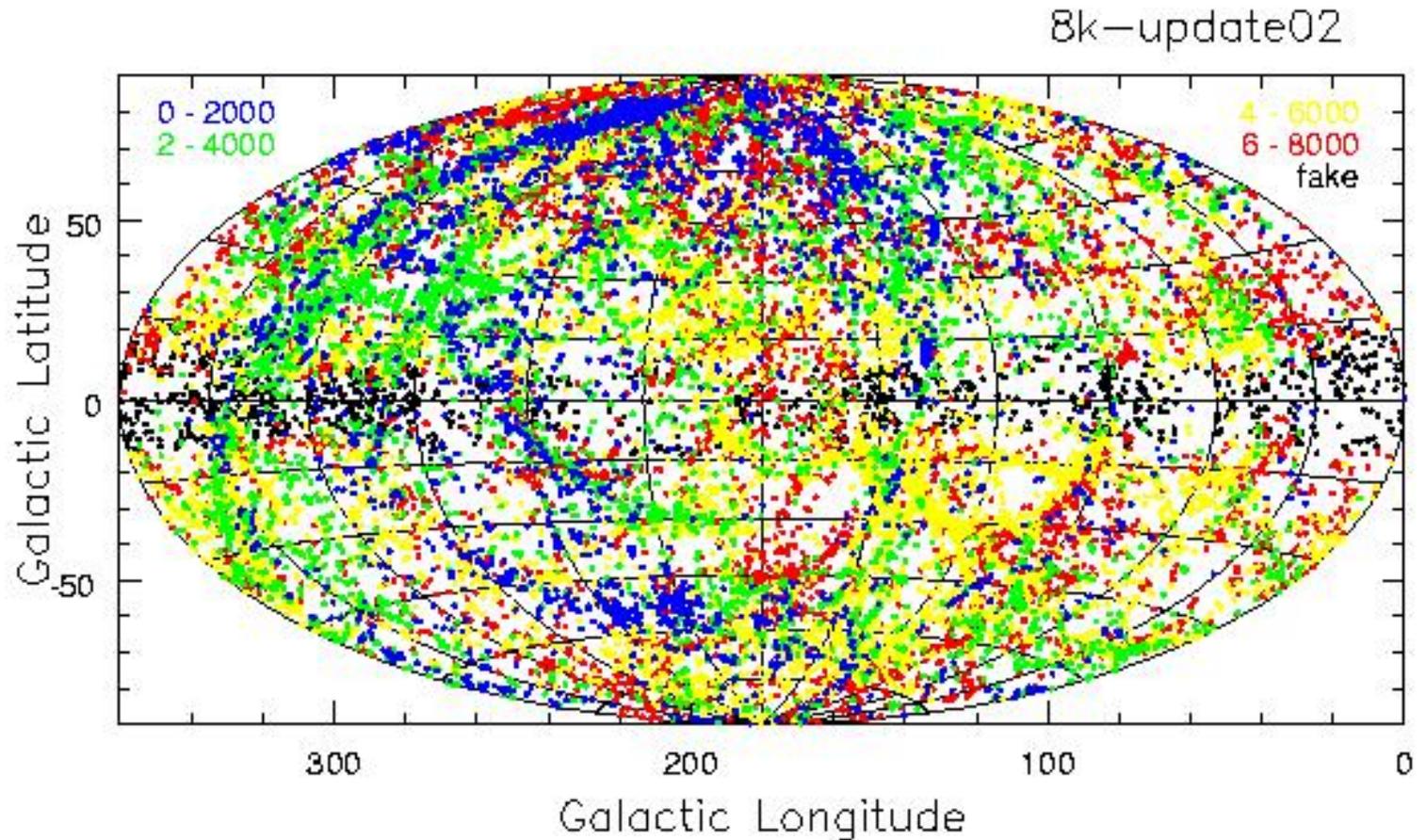


650 million light year cube



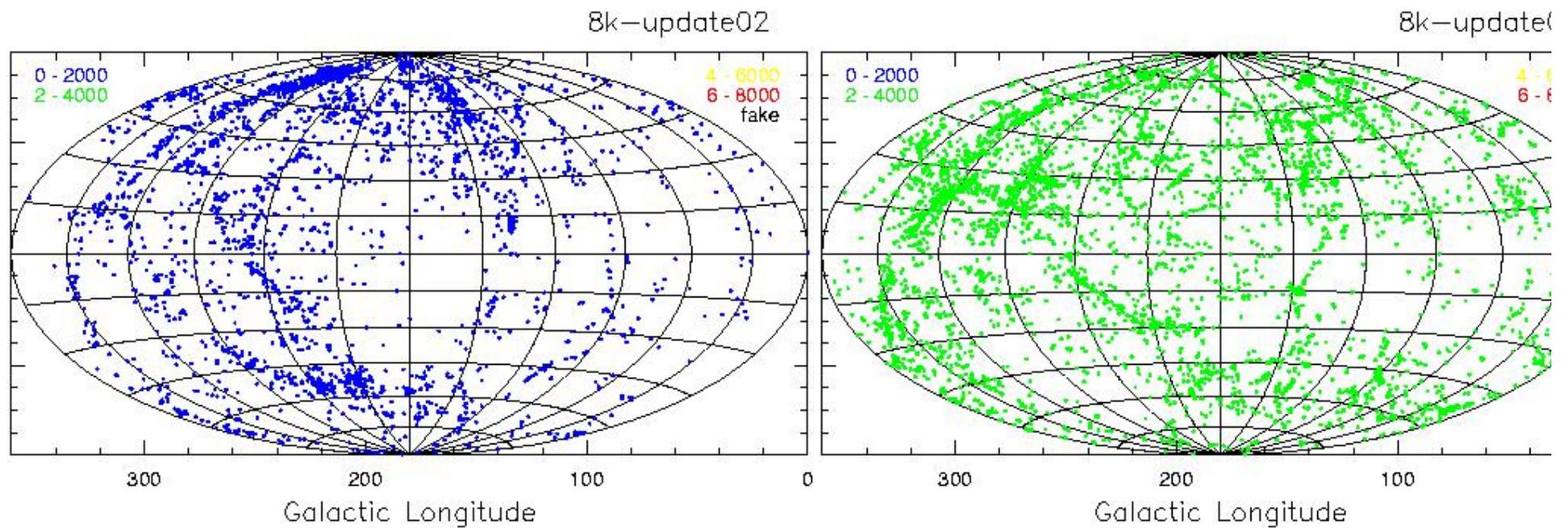
# aitoff projection

In this all-sky projection, each dot is a separate galaxy. Colors indicate distance from us (close to far running blue, green, yellow, red). Black points lie near the plane of our galaxy and have uncertain distances.



# shells

Here we see two separate shells in distance. Notice the prominent filamentary structures.



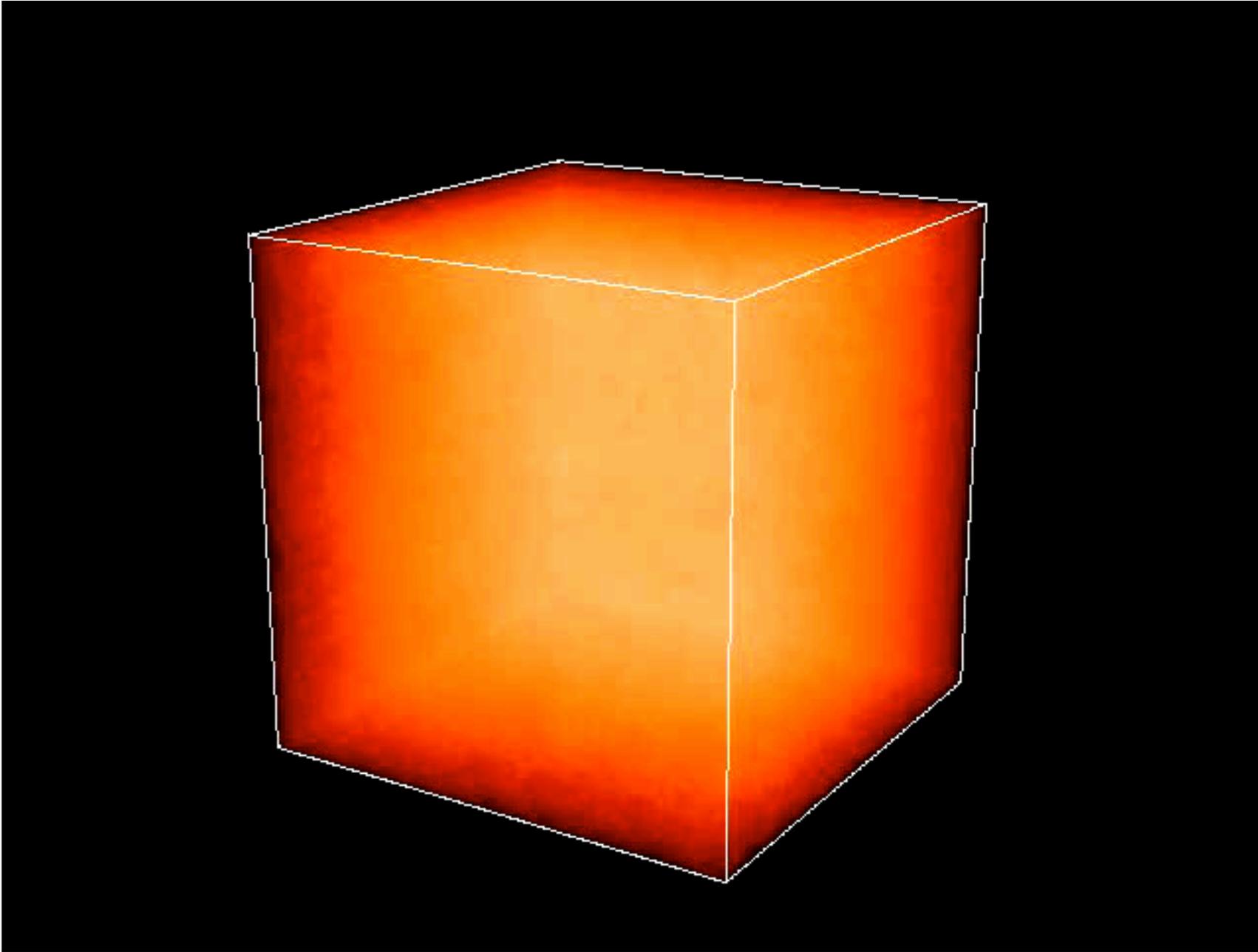
# The Structure Is Formed by the Relentless Pull of Gravity

- For the most part, gravity has not yet succeeded in fully pulling things together
- Dimensions are so great – in the entire life of the universe there has not been time for many places to collapse

The following slide contains a movie that illustrates the development of structure in a computer simulation.

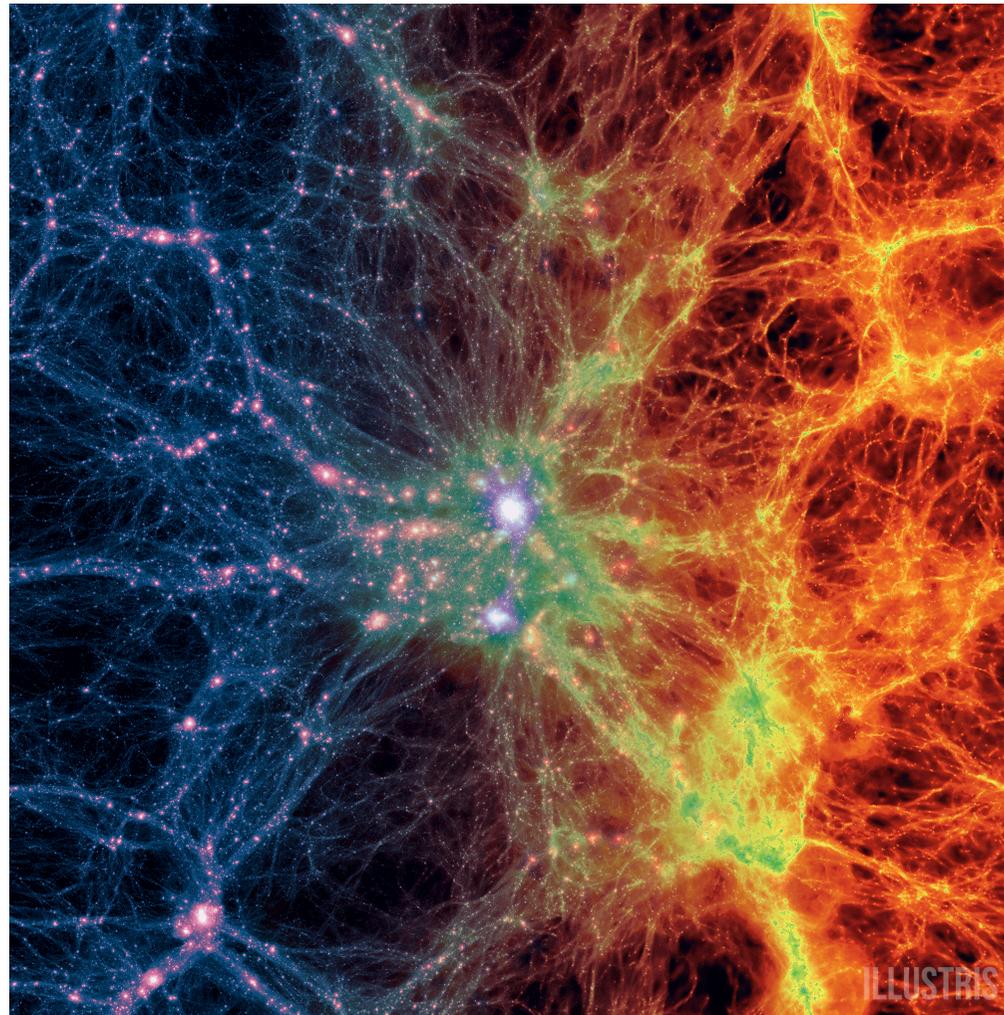
The next slide is another movie; this time a fly-through of the end result of a large simulation.

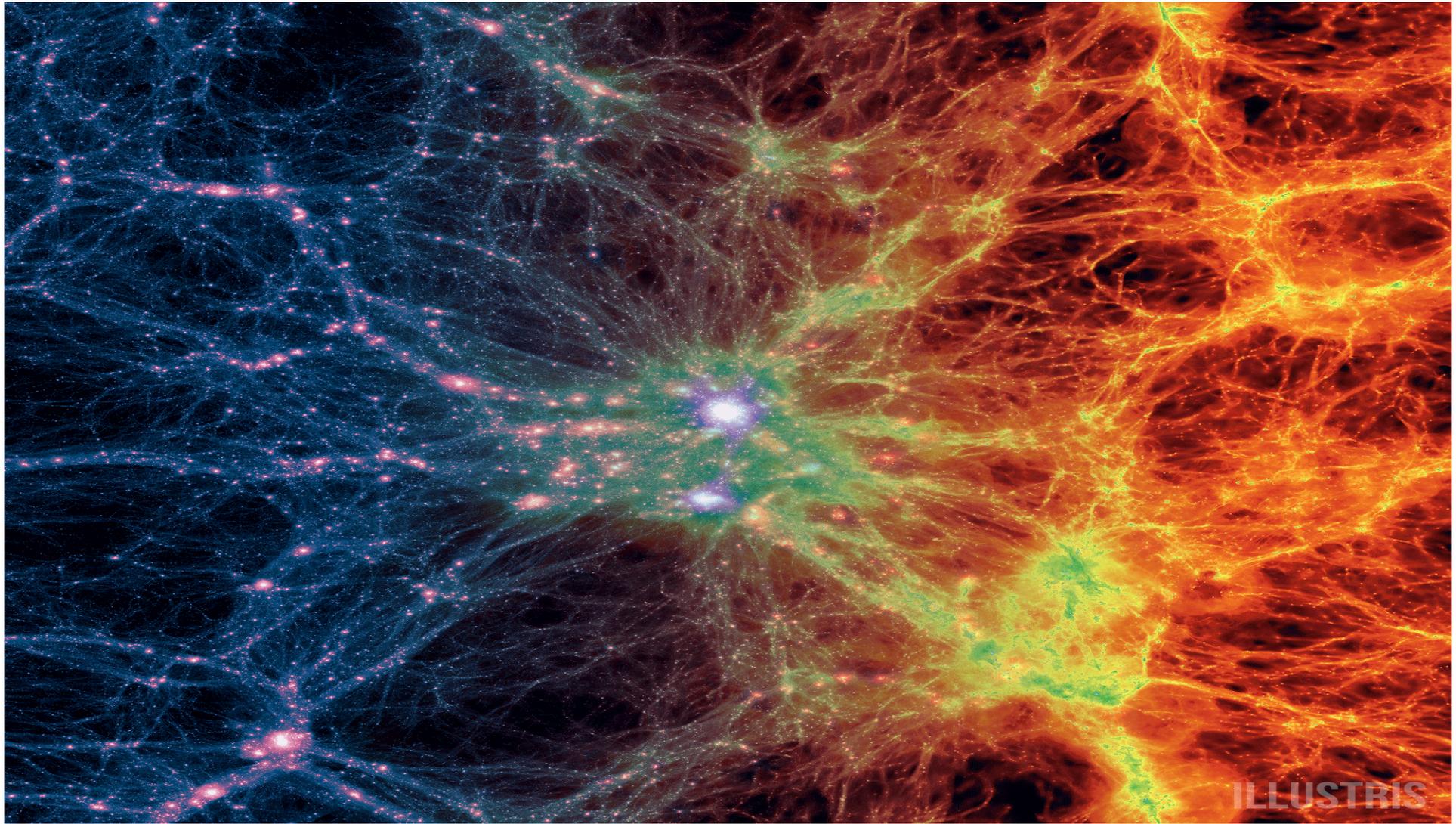
The slide after that is a movie involving real data: a flight from the Earth, through the Milky Way, to the Virgo Cluster.



millennium movie

<https://www.youtube.com/watch?v=SY0bKE10ZDM>





[www.ifa.hawaii.edu/~tully/outreach/movie](http://www.ifa.hawaii.edu/~tully/outreach/movie)

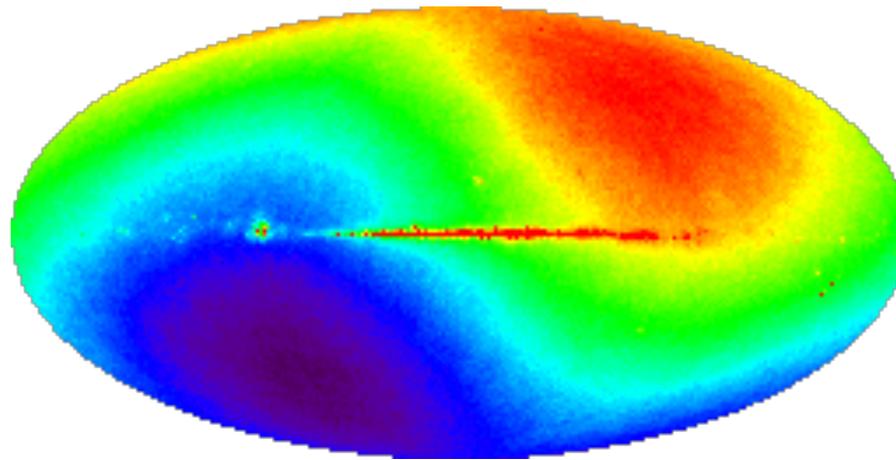
**Virtual Voyage:  
Milky Way to the Virgo Cluster**

**HDTV Visual Excerpt from "Runaway Universe"**

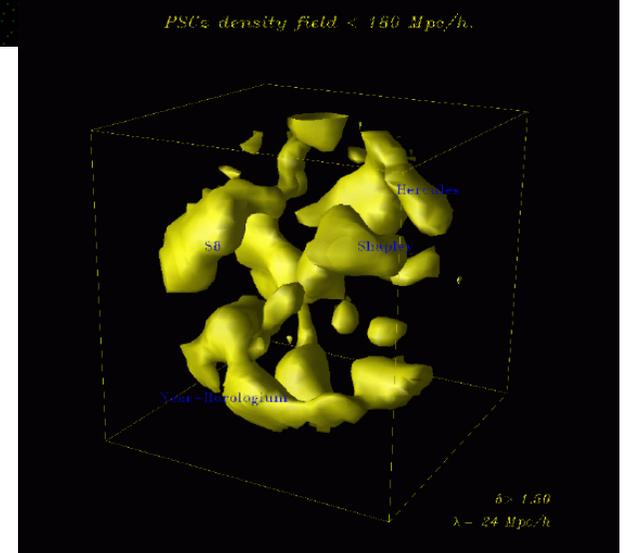
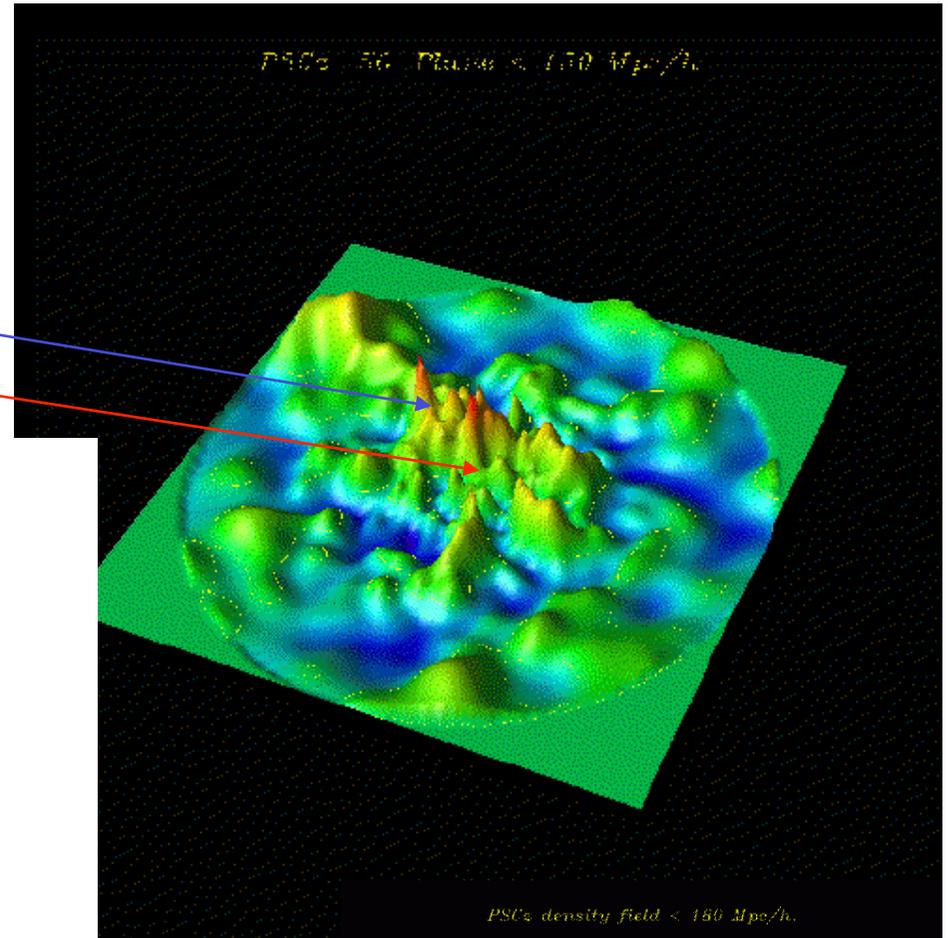
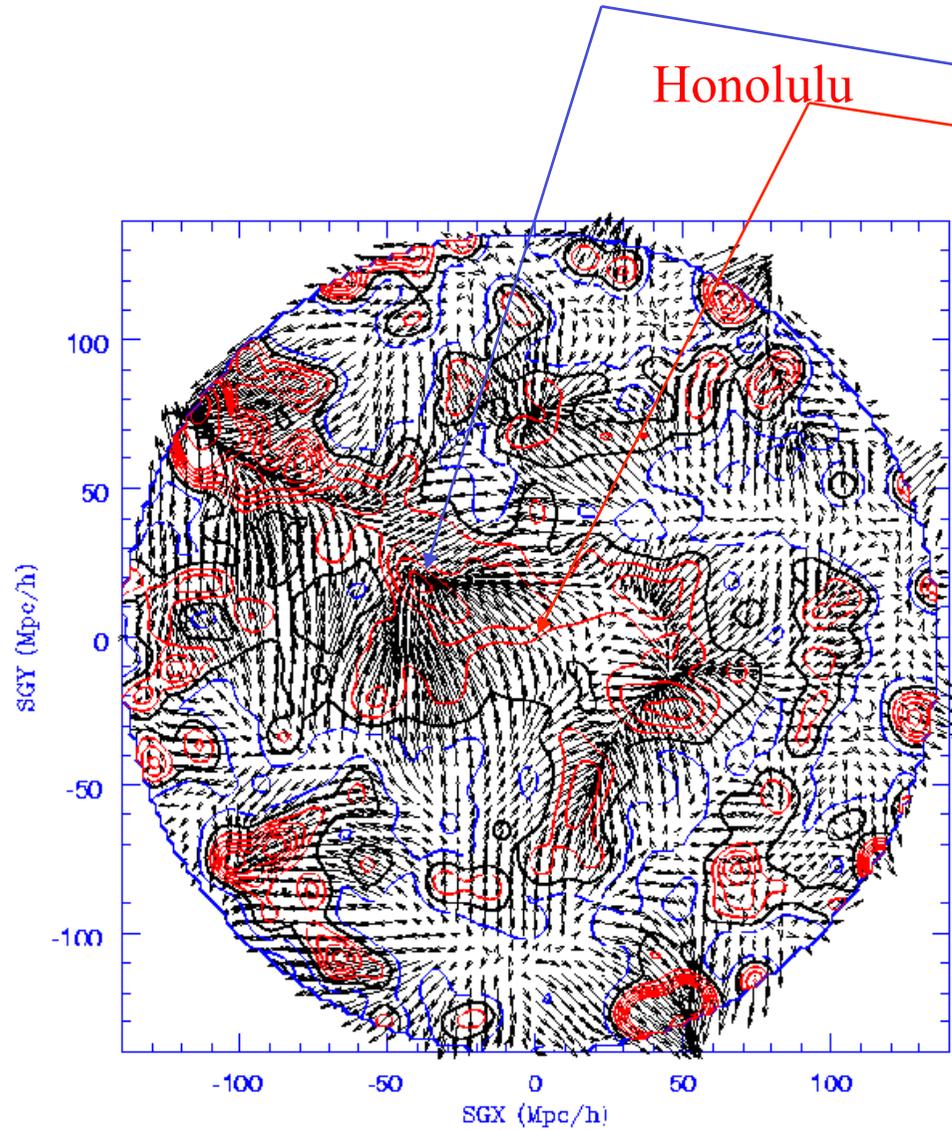
**Courtesy NOVA/WGBH, PBS**

**Tom Lucas Productions**

- We see the pulling effect of gravity in the relative motions of galaxies
- Galaxies are moving toward the largest concentration of galaxies
- We are moving at 600 km/s toward a region in the sky called the Great Attractor



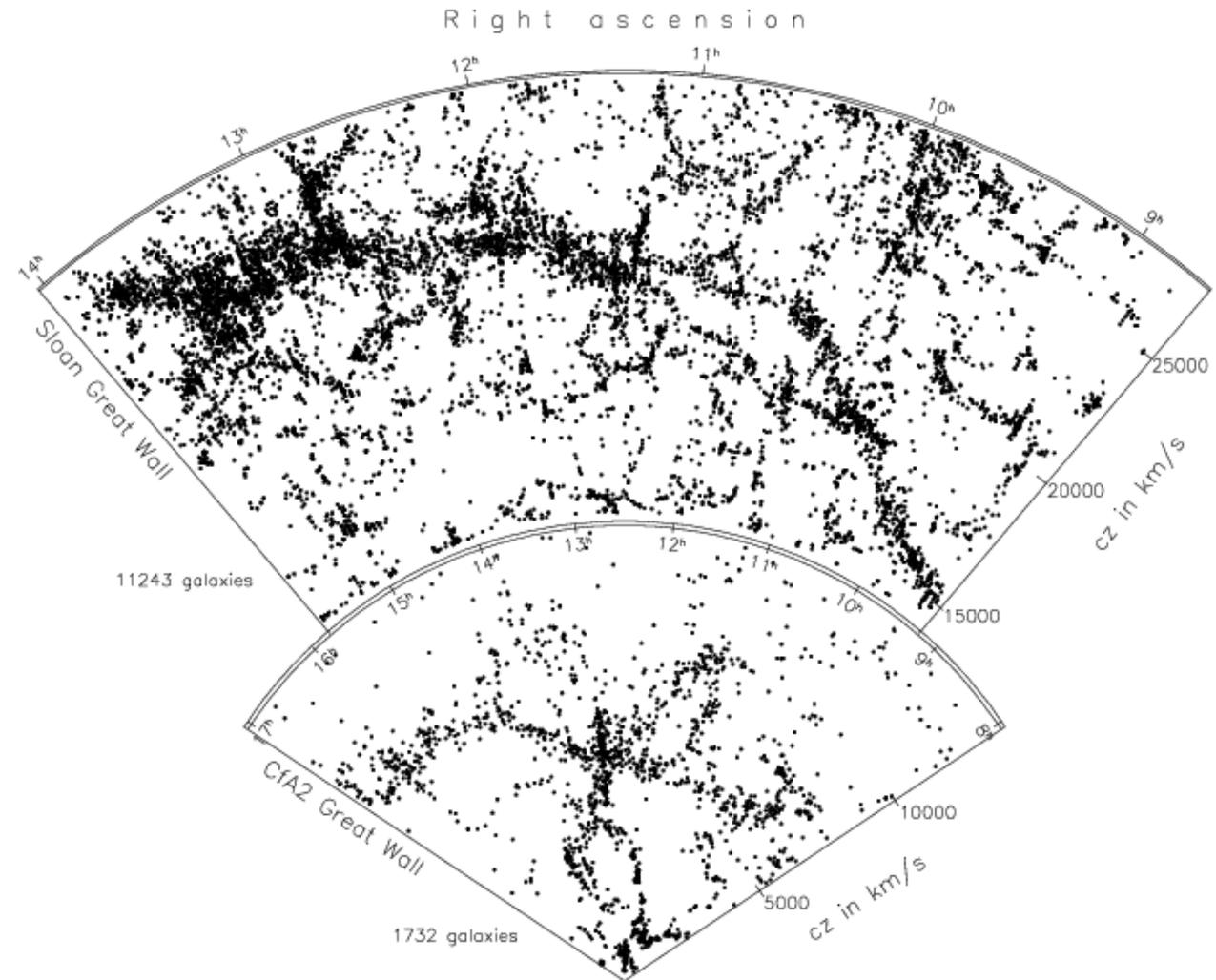
# Great Attractor region



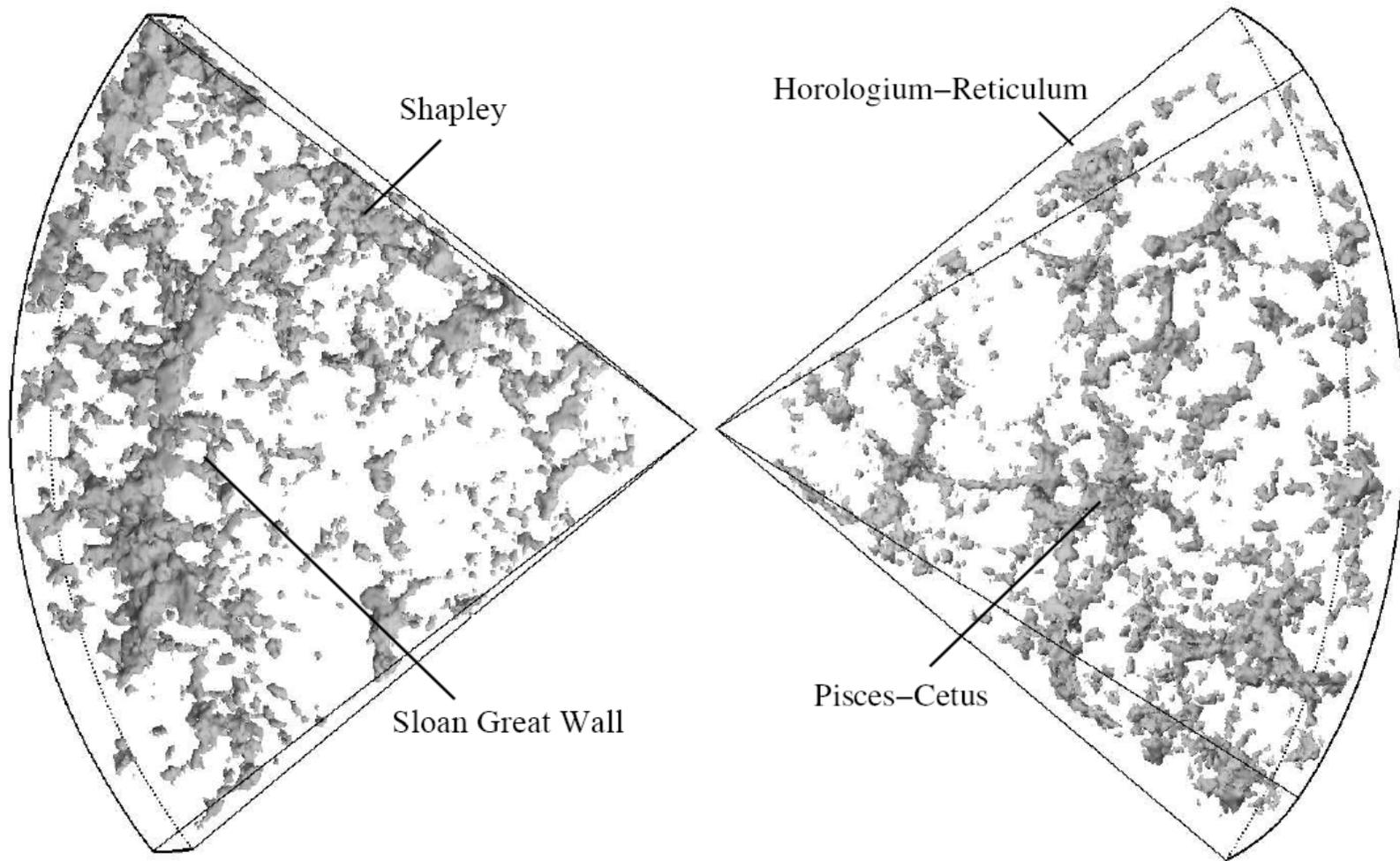
Yet, overall, the expansion of the universe is winning! Especially, as we now think, if the expansion is actually speeding up

- Eventually galaxies that haven't collapse into a group or cluster will speed farther and farther apart
- The filamentary structure we see today will be stretched thinner and thinner until it is no longer apparent

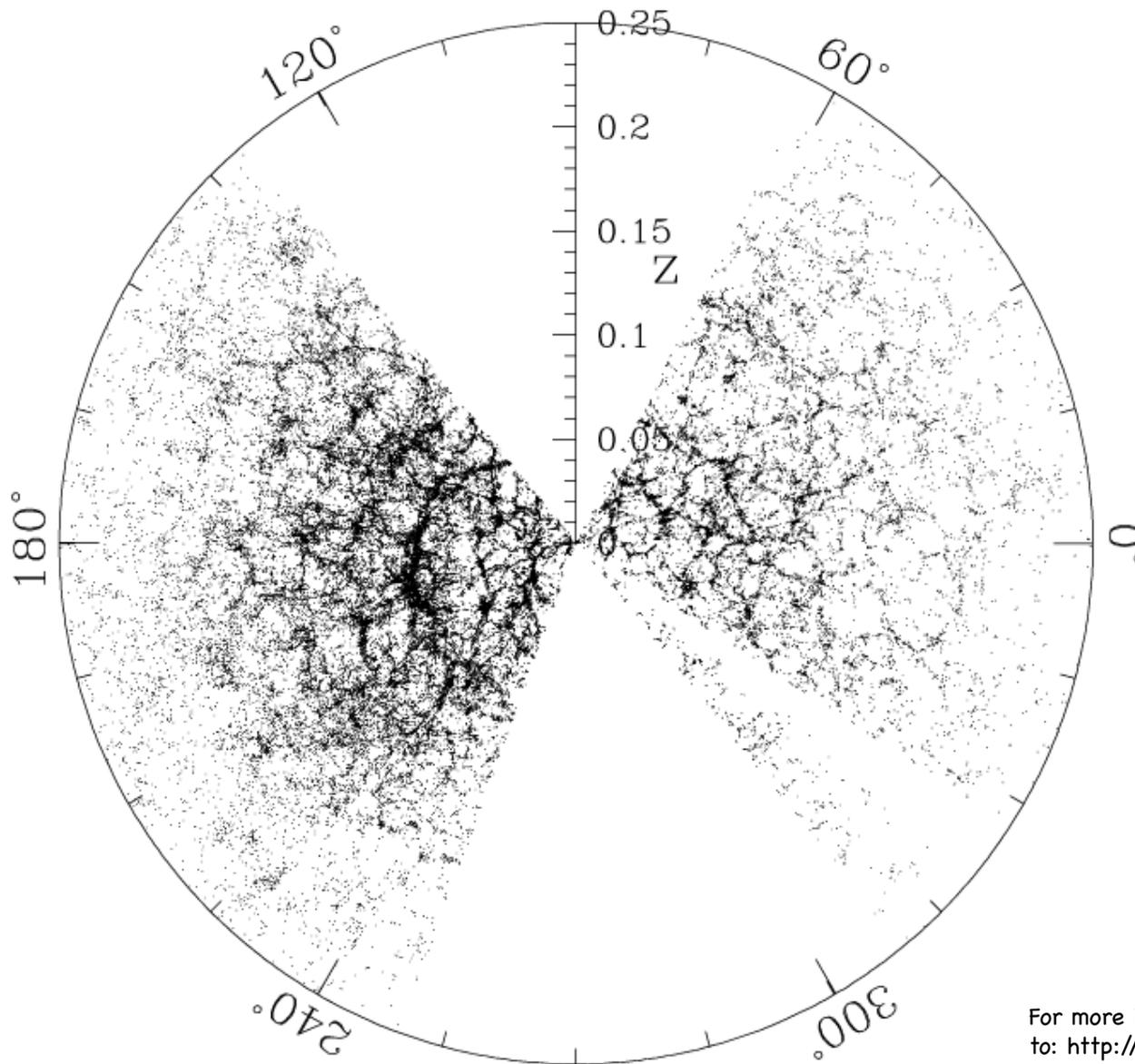
# The original CfA2 Great Wall and the Sloan Great Wall



## major nearby structures



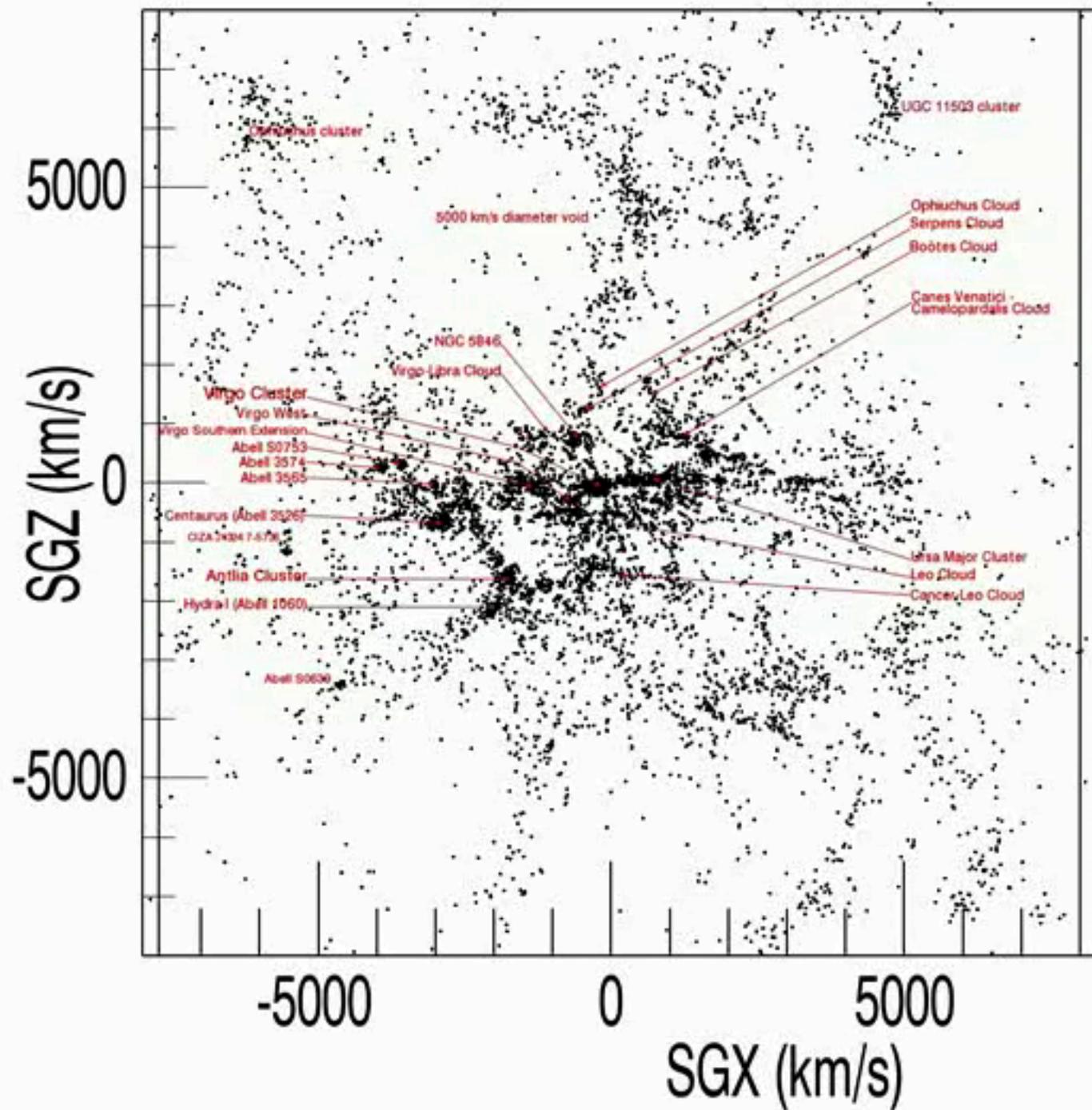
Blanton et al. (2003) (astro-ph/0210215)



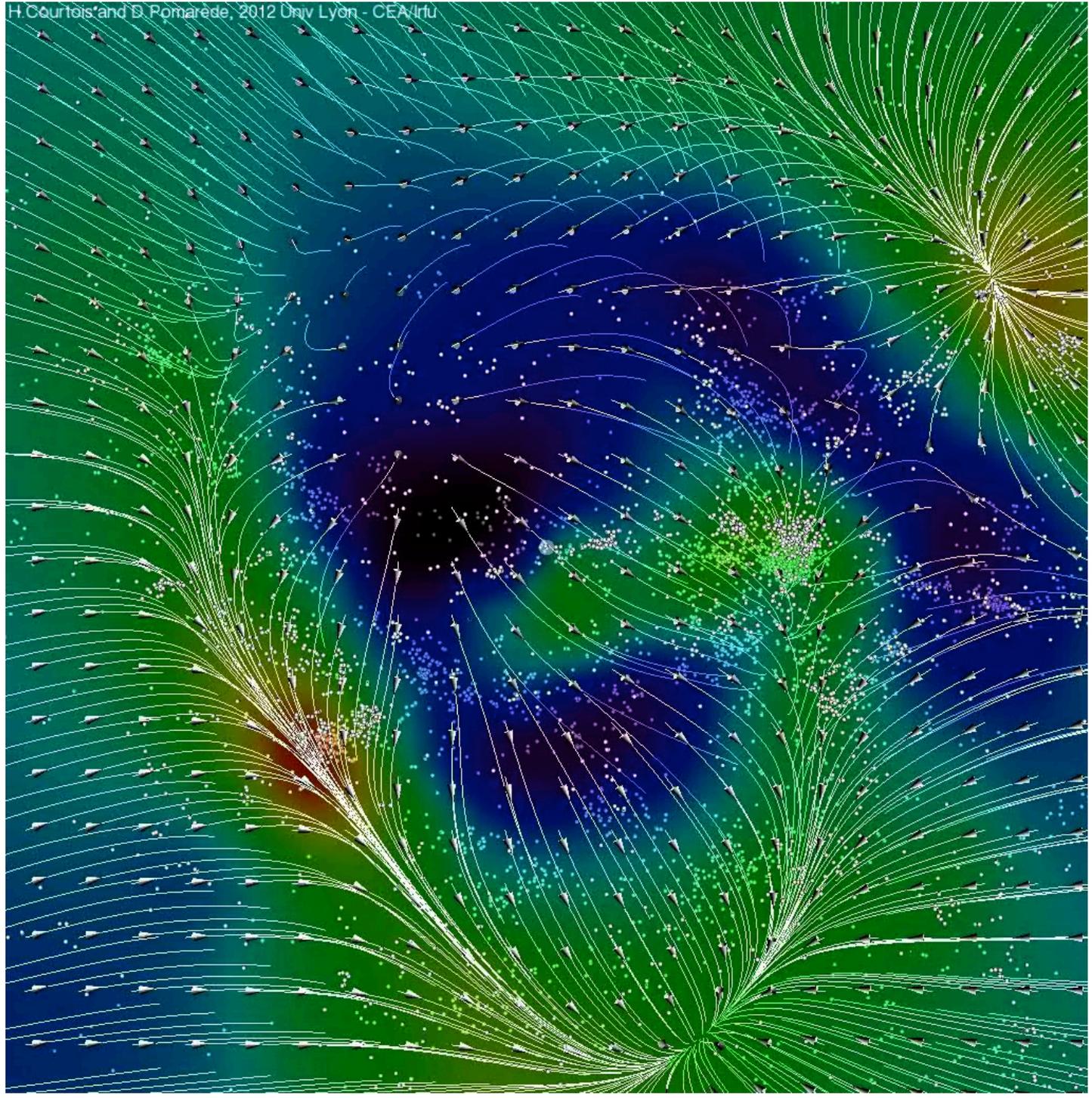
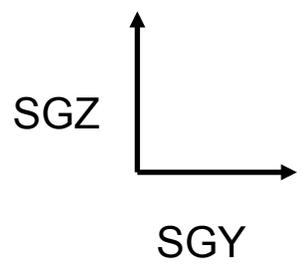
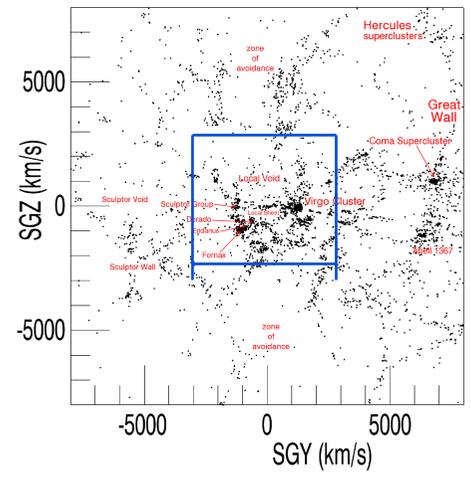
Sloan Digital Sky  
Survey

For more images and movies of large scale structure go  
to: <http://www.ifa.hawaii.edu/~tully/outreach/>

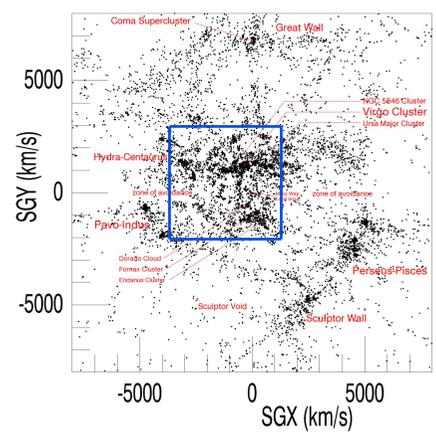
Large-Scale Structure sample10



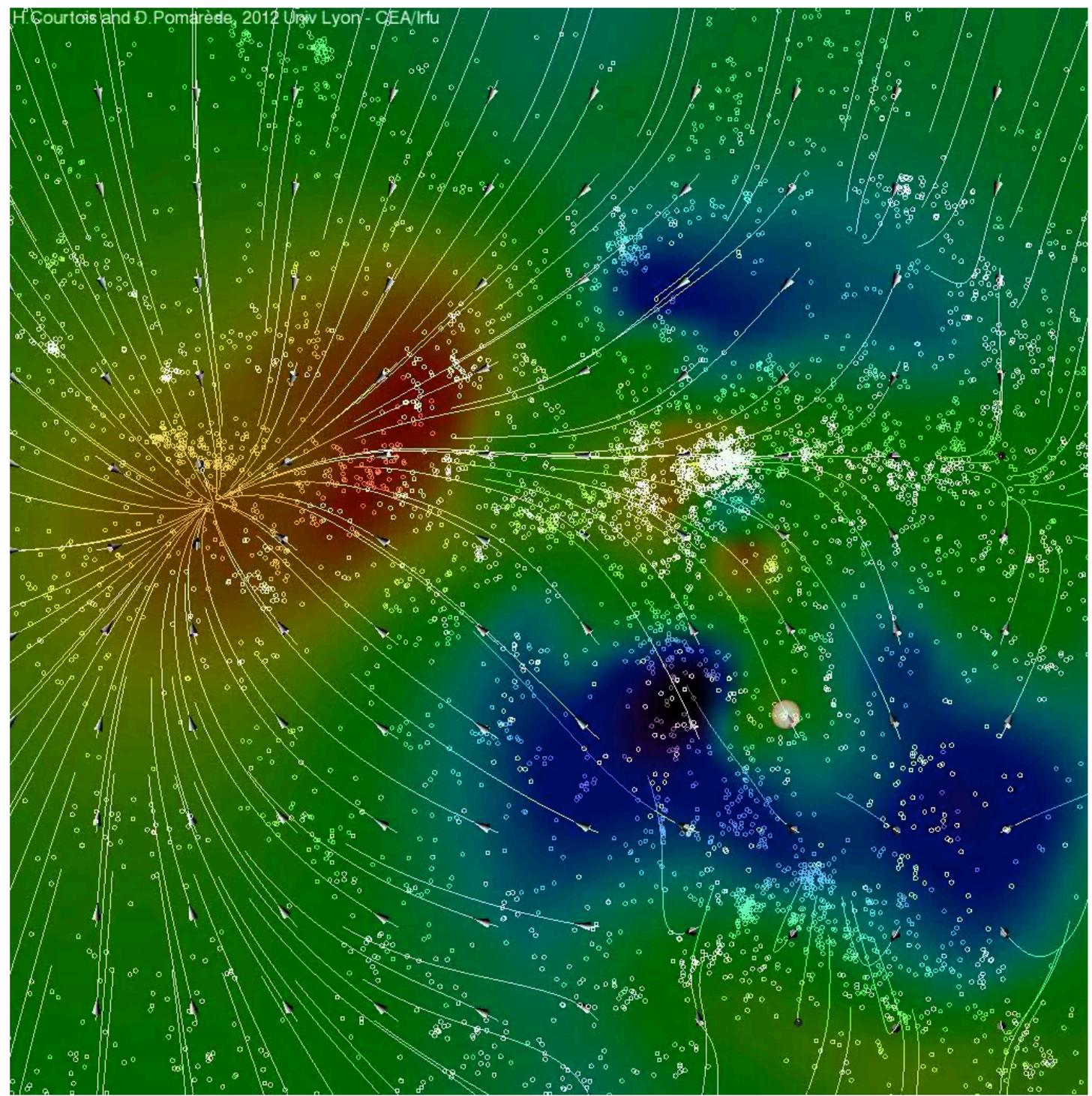
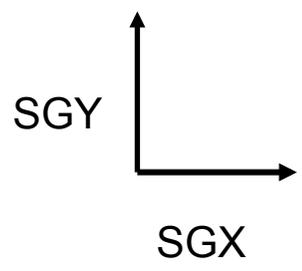
Results from cosmicflows-1  
Expulsion from the Local Void.



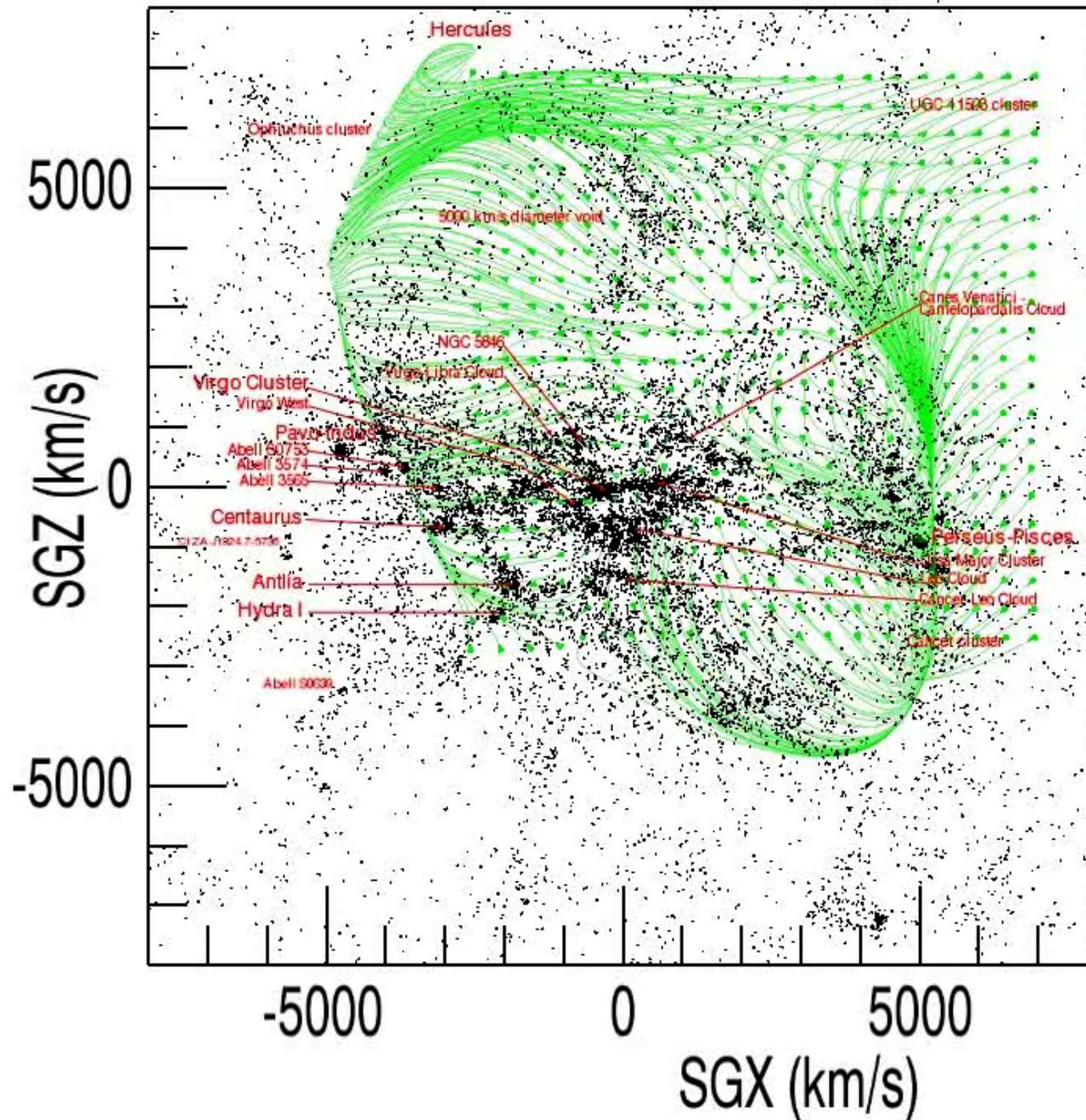
Results of cosmicflows-1  
our location with regard to  
a chain of attractors

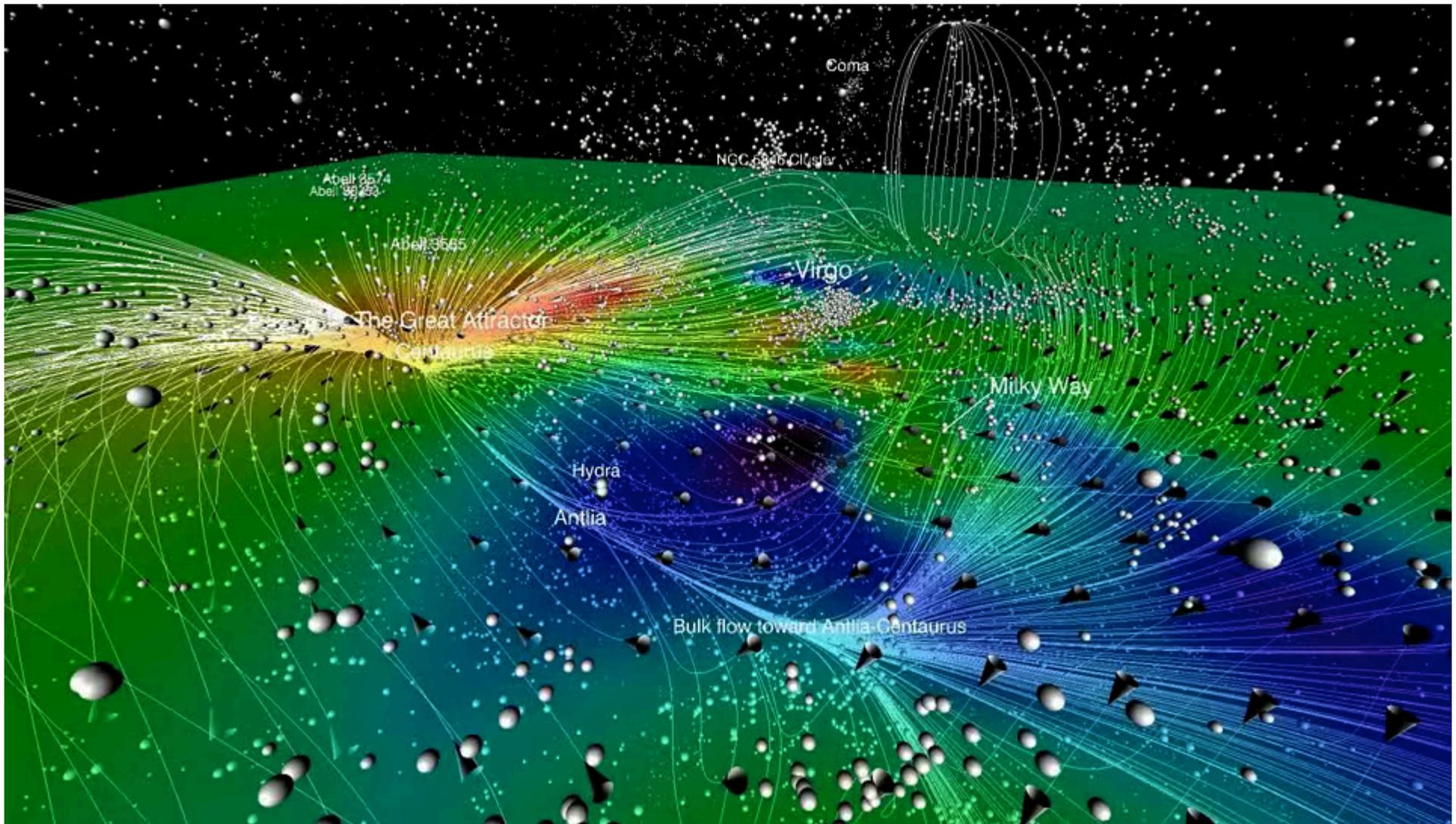


Centaurus Cluster



# Preliminary Weiner Filter result from Cosmicflows-2





## Major results:

- Wiener filtering of observed flows gives density maps in accordance with observed features.
- Flows out of voids into filaments collecting at nodes of major clusters.
- Smooth local flows with velocity discontinuities between structures.

Google: Cosmography of the Local Universe



