Helene COURTOIS

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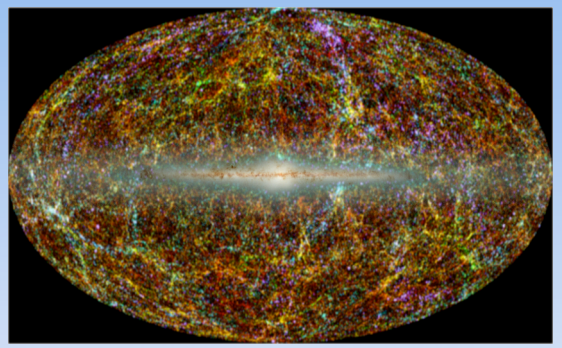
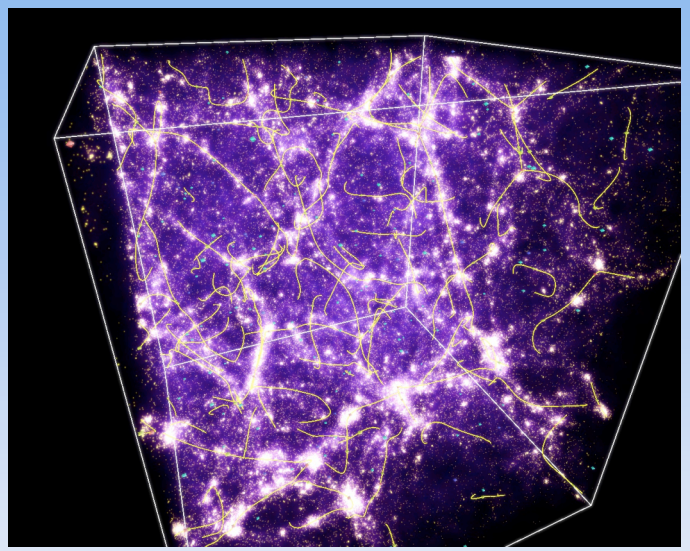
Cosmic Flows in the Local Universe

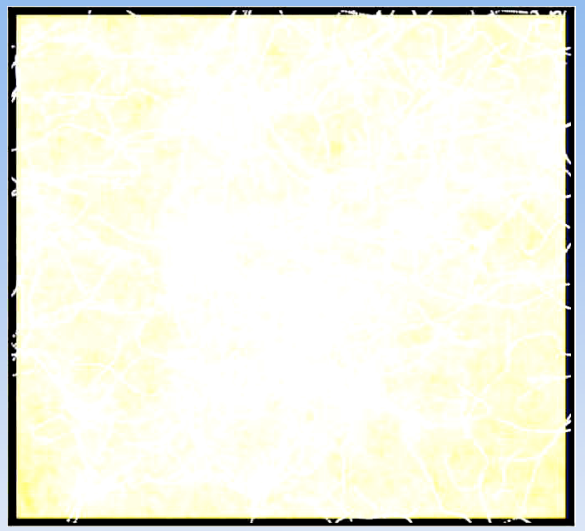
COSFLOS Collaboration :

Tully, Fisher, Rizzi, Karachentsev, Kraan-Korteweg, Koribalski, Bonhomme, Forero, Sousbie, Makarov, Gottloeber, et al.

Cosmic Flows : measuring galaxies rotational velocities --> to measure distances --> to draw large scale motions --> to recover the field mass --> to recover the dark matter and dark energy densities in the local universe.

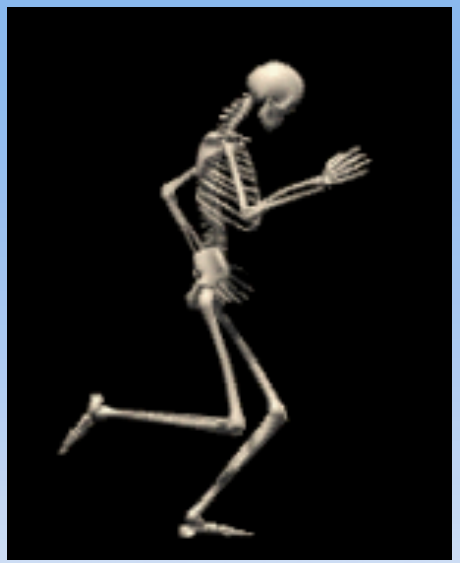






When one knows about the 3D skeleton, one doesn't know everything …. 4D obs needed

DM exotic particles ?



LCDM , quintessence ?

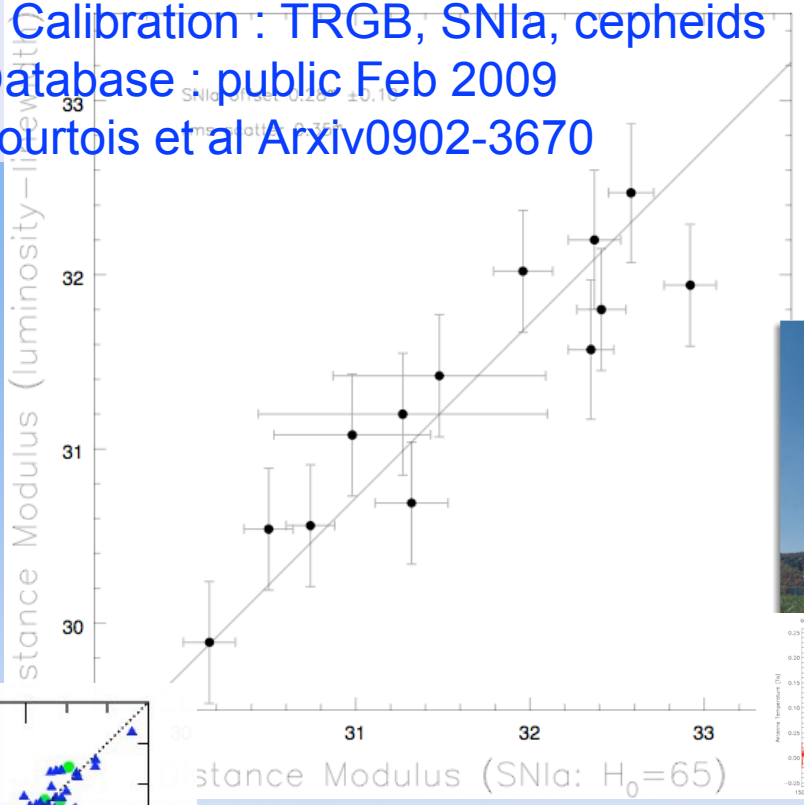
Dark Fluid, ordinary matter?

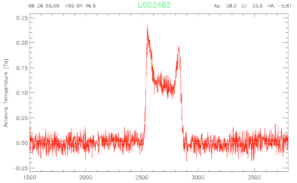
• Numerical Simulations from CMB Initial conditions are very advanced --> constrained on the local universe. Advanced analysis and visualisation techniques on their way ….

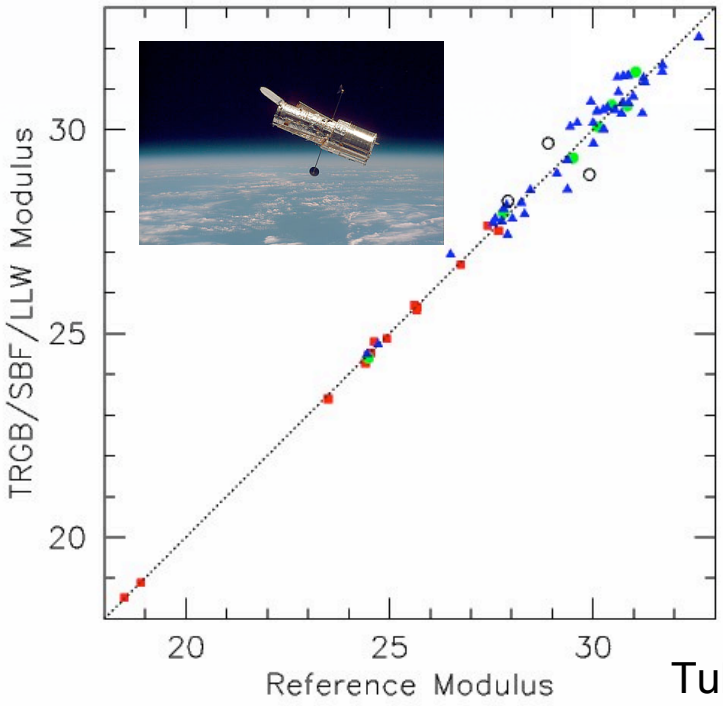
• Spooky, or simple, or elegant theories are available : dark fluid scalar field (mimics gravitation, expansion, DM, dark energy : all in one energy description), back reaction from inhomogeneities (Kolb)

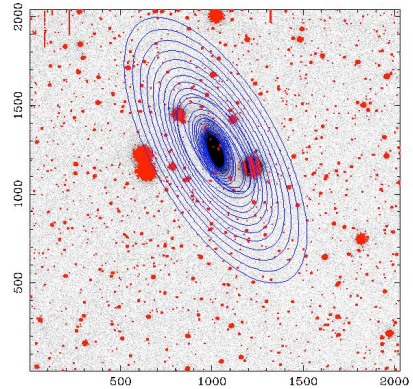
• Observational Needs : 4D data peculiar motions == distances ($V_{obs} = V_{grav} + V_{exp}$; $V_{exp}=H_o$ x d)
Nearby 10Mpc : cepheids, TRGB
Further 300Mpc : SNIa , long HI exposures, long NIR exposures for SB, very large coverage of the sky.

HI Data + Surface photometry + Calibration : TRGB, SNIa, cepheids
→EDD Extragalactic Distance Database : public Feb 2009
→Tully et al. Arxiv0902-3668, Courtois et al Arxiv0902-3670
http://edd.ifa.hawaii.edu









Tully et al. 2008 ApJ 676, 184

EDD
Extragalactic Distance Database

COSFLOS Cosmic Flows

http://edd.ifa.hawaii.edu/

http://ifa.hawaii.edu/~cosmicflows

Cosmic Flows home http://ifa.hawaii.edu/cosmicflows/

Project: GBT08c-010
484 hours awarded
Project start date:
Semester 08C

- NRAO Large Program
- Cosmic Flows Proposal
- Green Bank Telescope
- Extragalactic Distance Database
- Pan-STARRS

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Bulk Motions of Filaments in the Local Universe

- **Team Members:**
  Hélène Courtois, *Université Lyon 1*
  R. Brent Tully, *UH Institute for Astronomy*
  J. Richard Fisher, *National Radio Astronomy Observatory*
  Nicolas Bonhomme, *Université Lyon 1*

- **Project Description:**
  Galaxies acquire motions that deviate from the universal expansion through gravitational interactions on a wide range of scales. The radial component of these deviant motions can be mapped with accurate measurements of distances. One of a variety of ways to measure distances makes use of the correlation between the luminosities of galaxies and their rotation rates. With appropriate photometric and spectroscopic information, the method can be applied to a majority of spiral galaxies. Samples of many thousands of galaxies can be acquired, giving the dense spatial coverage required to study the streams and eddies in the Cosmic Flow.

  Photometry to measure the luminosities of galaxies has been carried out at optical bands with telescopes at Mauna Kea Observatory and a tremendous advance is about to be realized with the implementation of digital all-sky surveys, foremost with Pan-STARRS in Hawai'i. Information about galaxy rotation rates is derived from observations of global 21cm Hydrogen line profiles. Data are accumulated at a variety of telescopes to assure full sky coverage but foremost in importance for the project is the Robert C. Byrd Green Bank Telescope because of its sensitivity and access to most of the sky.

  The Extragalactic Distance Database (EDD) has been developed to give access to the diverse information involved with the measurement of galaxy distances. The results of observations made during the course of this program will be made available within the catalog 'All Digital HI' in EDD. Original optical photometry is made available in EDD through the catalog 'Hawaii Photometry'.

- **Publications**
  "Our Peculiar Motion away from the Local Void"
  RB Tully, E.J. Shaya, ID Karachentsev, HM Courtois, DD Kocevski, L Rizzi, A Peel
  2008, ApJ, 676, 184

  "Distances in the Local Universe: New HI and I Band Surveys"
  HM Courtois, RB Tully, JR Fisher
  2007, BAAS, 38, 330

  "Derivation of Distances with the Tully-Fisher Relation: The Antlia Cluster"


The Local Universe

A typical target
-HI line profile
-surface brightness profile
-mask and ellipse fit

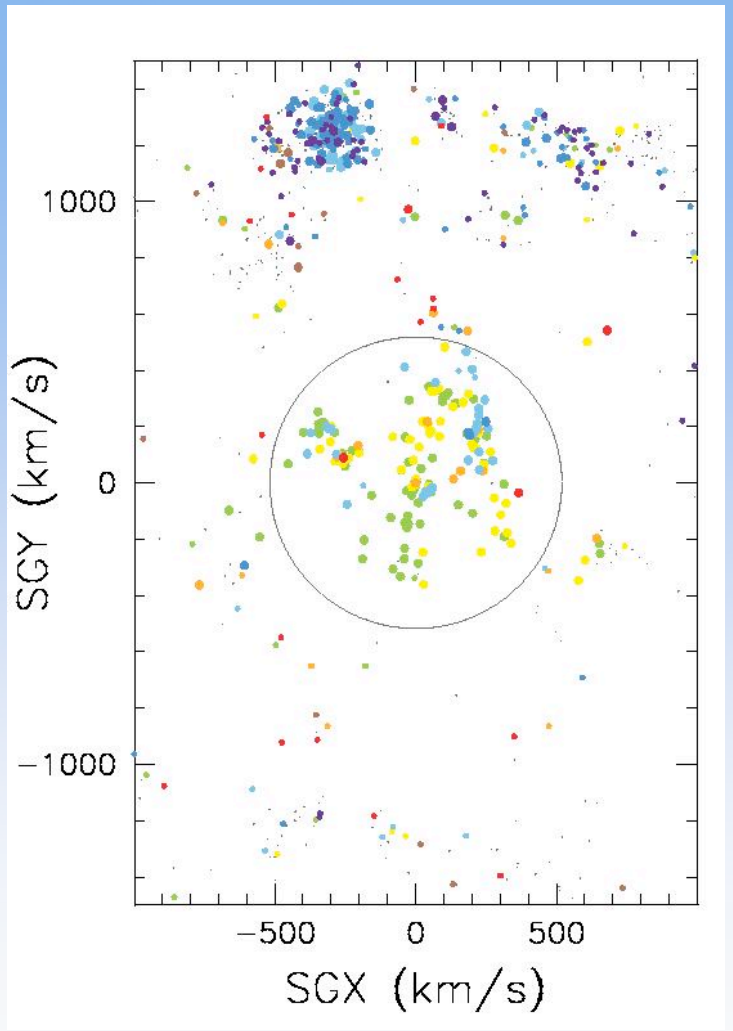
Measuring distances
-5 cluster template
-zero point calibration
-consistency

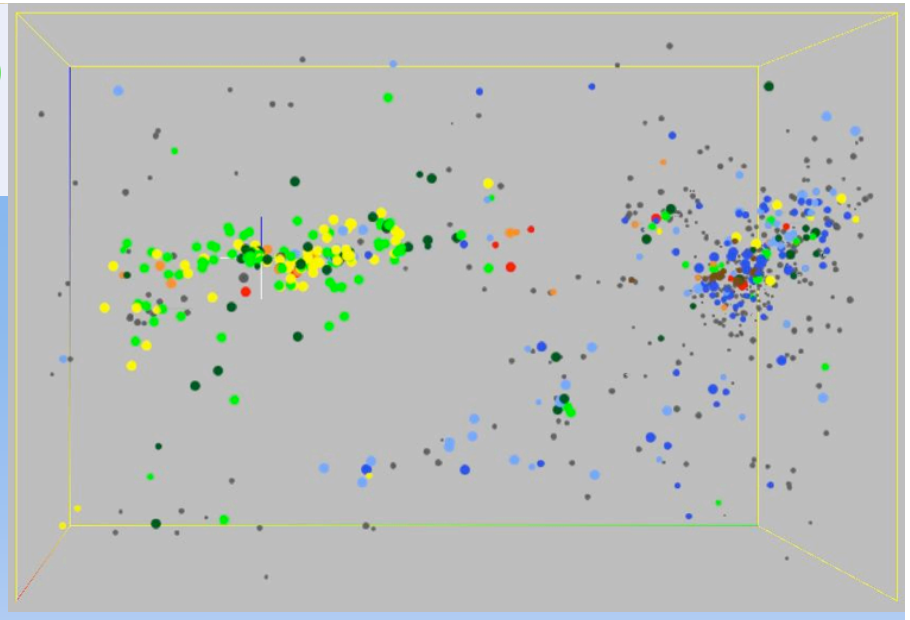
Preliminary results
-Local Void


Robert C. Byrd
Green Bank Telescope

green/yellow V_{pec}~0
red V_{pec} > +100
blue V_{pec} < -100

Pole-on to Supergalactic plane





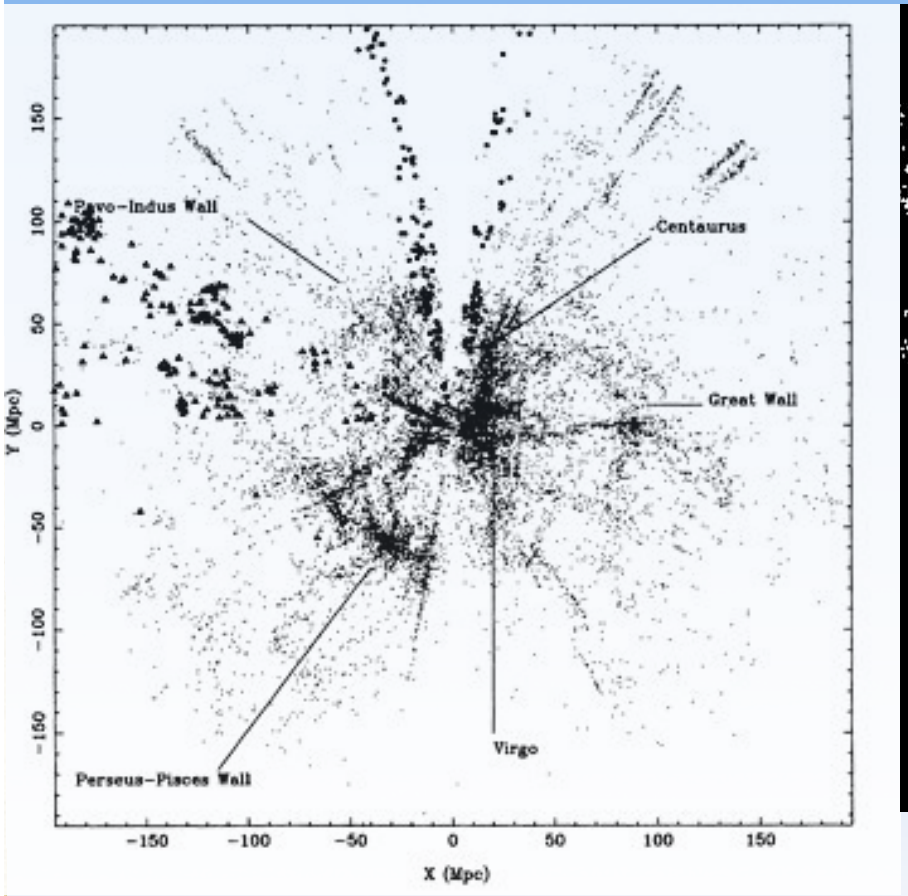
Edge-on to Supergalactic plane

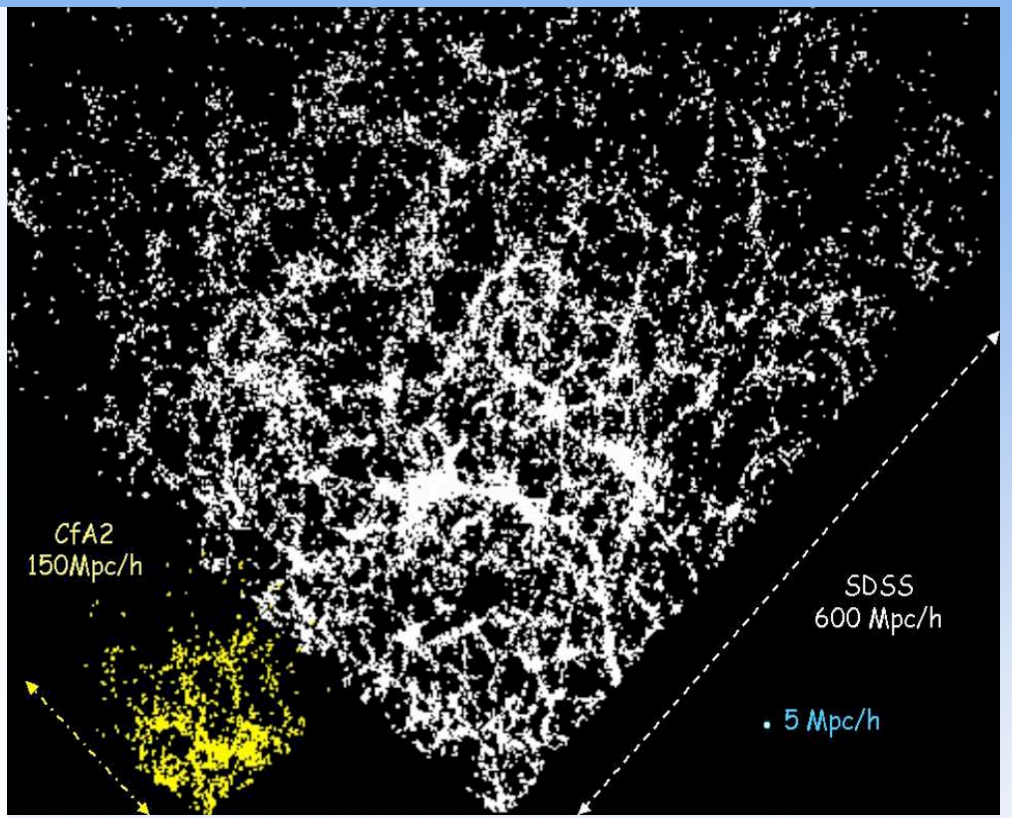
• co-moving motion of the Local Group w.r.t. 159 galaxies at 1.1 < d < 7 Mpc is 9 km/s negligible!!

• velocity dispersion about the local expansion of groups and galaxies outside of groups is ~40 km/s within the Local Sheet
(Karachentsev et al. 2003, AA, 398, 479) cold flow!!

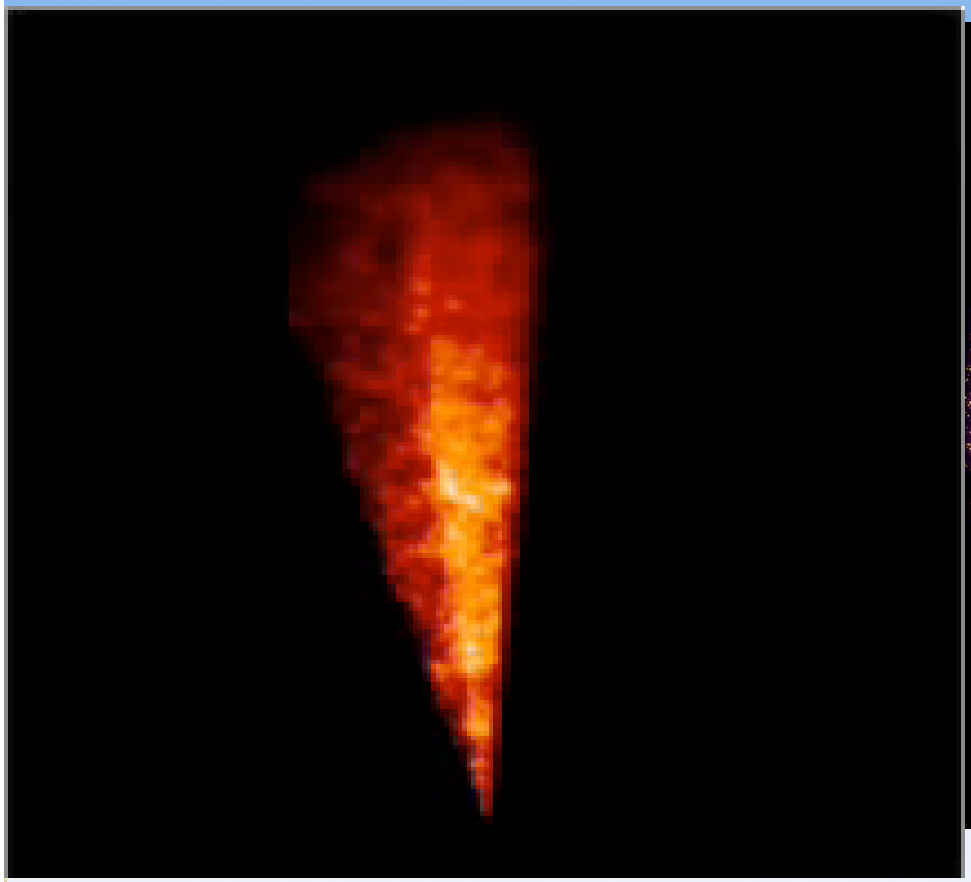
We are traveling with the Local Sheet as a unit
The Local Sheet is a wall bounding the Local Void

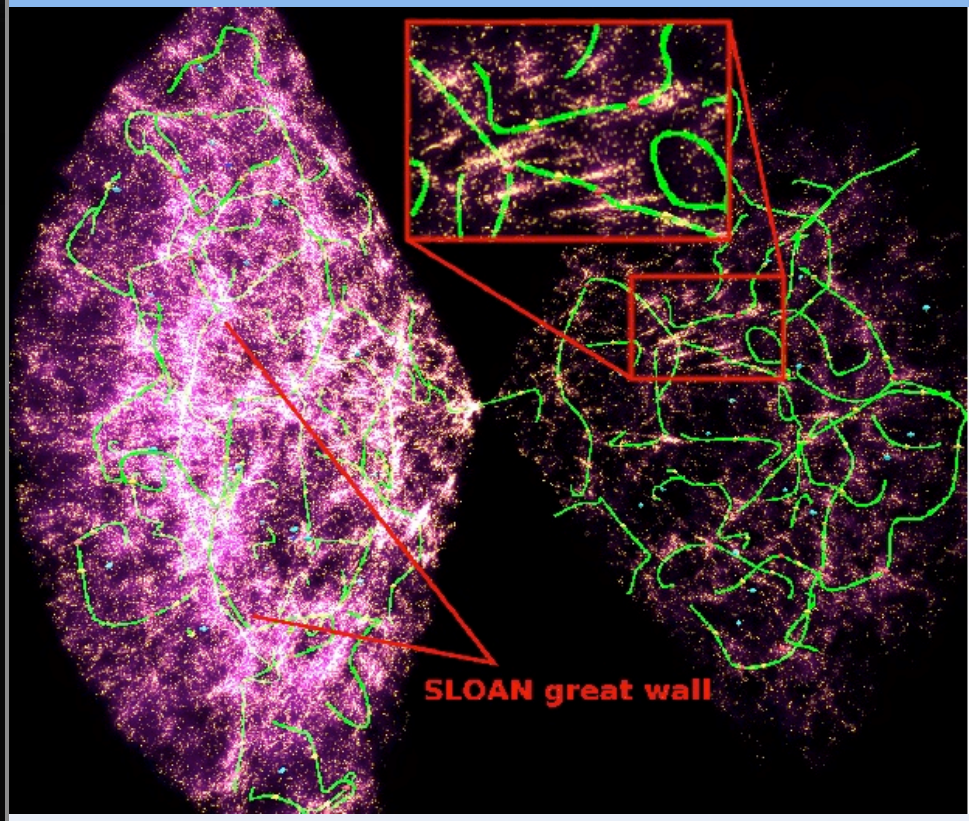
Galaxy structures : evolution of observations in 15 years 94-2009 : FLAIR (UKST), 2DF, SDSS : multifibers





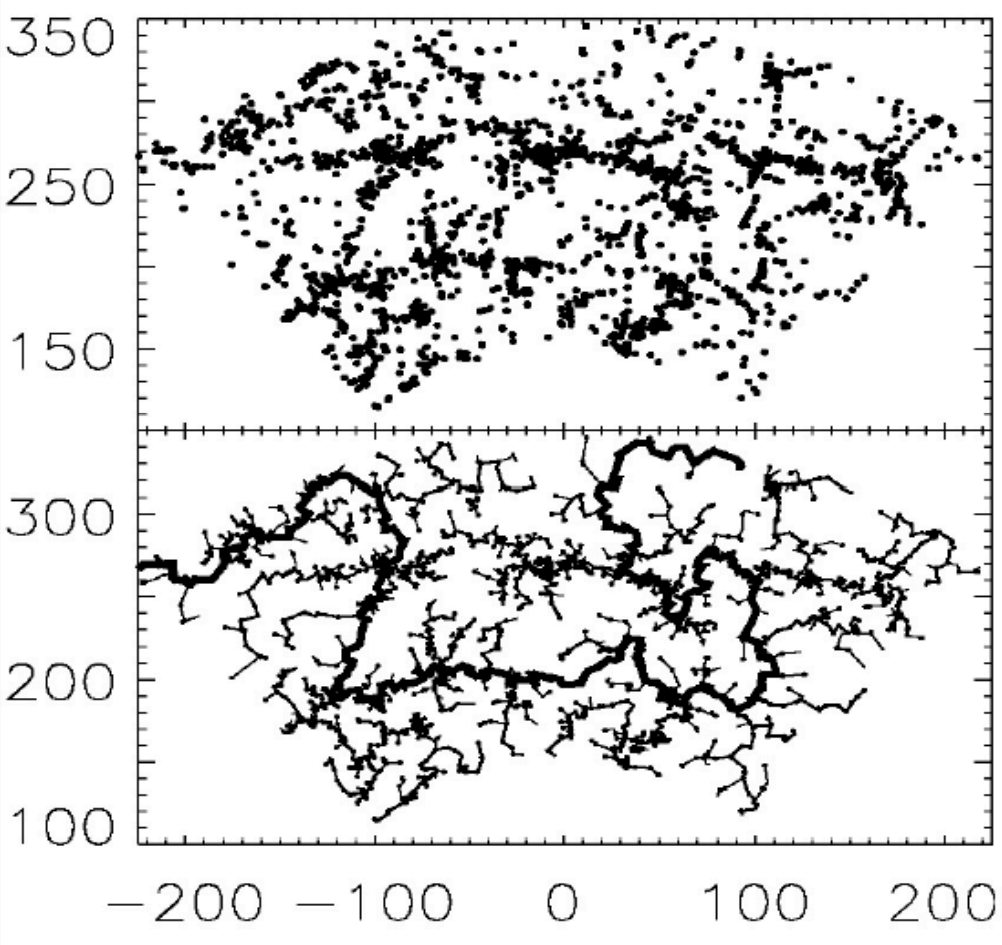
Galaxy structures : evolution of observations in 15 years 94-2009 : FLAIR (UKST), 2DF, SDSS : multifibers





Context : other Methods

Minimal spanning tree



Doroshkevich, A. G. et al. 2001, mnras, 322, 369

Cons

- Non local
- No analytic predictions possible
- Definition of a filament ?
- Discreteness

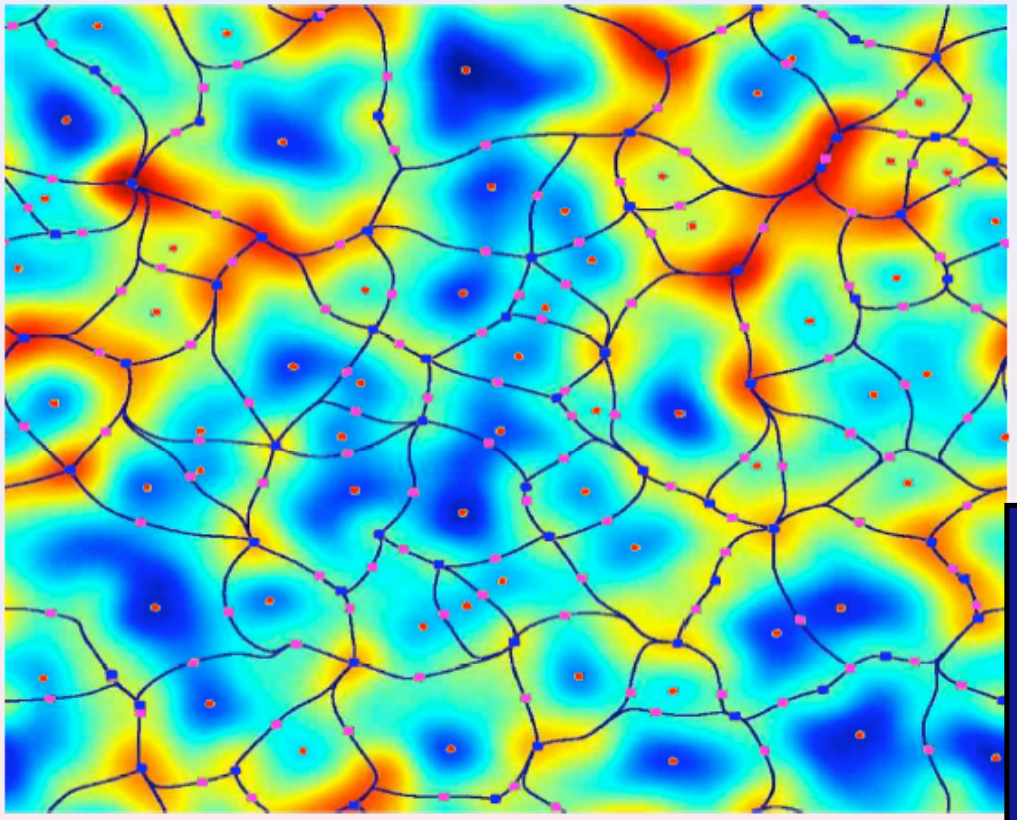
also Adhesion model (Burgess)...

The Skeleton: Definition

from Morse Theory

$\equiv$ critical lines frm max to saddle $\cong$ "crest lines"

$$\dot{\mathbf{r}} = \nabla \rho$$

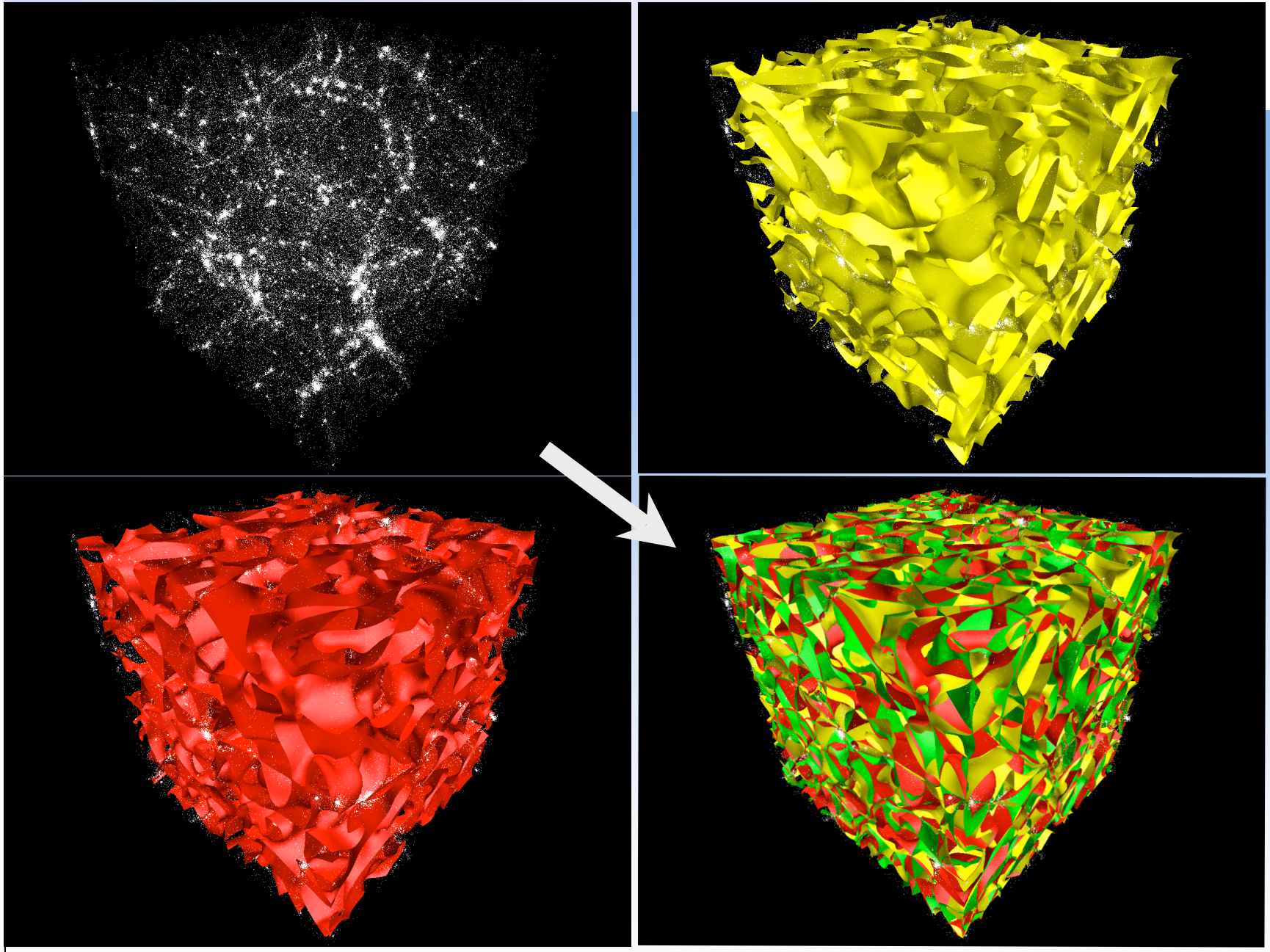


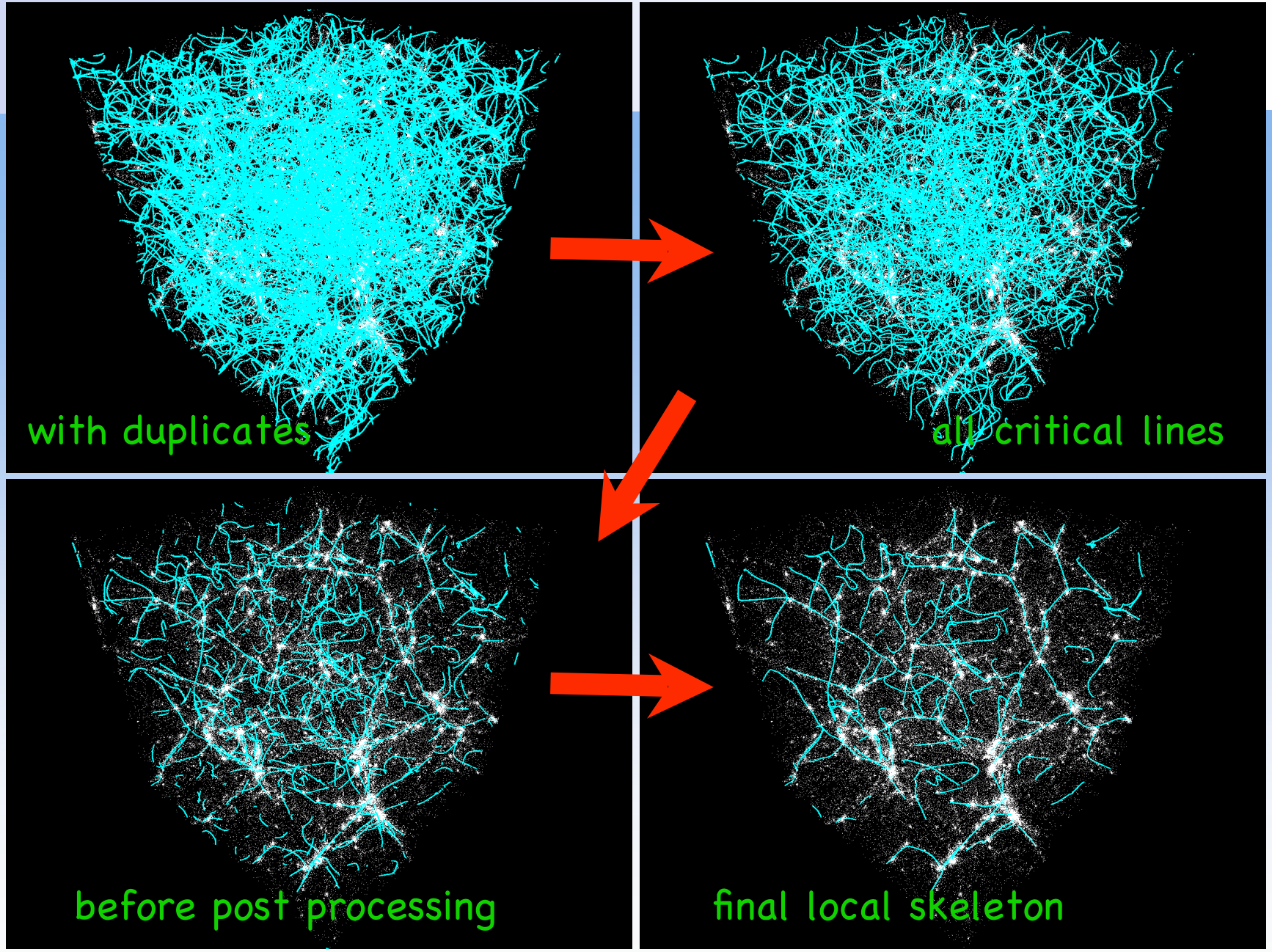
Novikov & al., 2006, MNRAS

Method

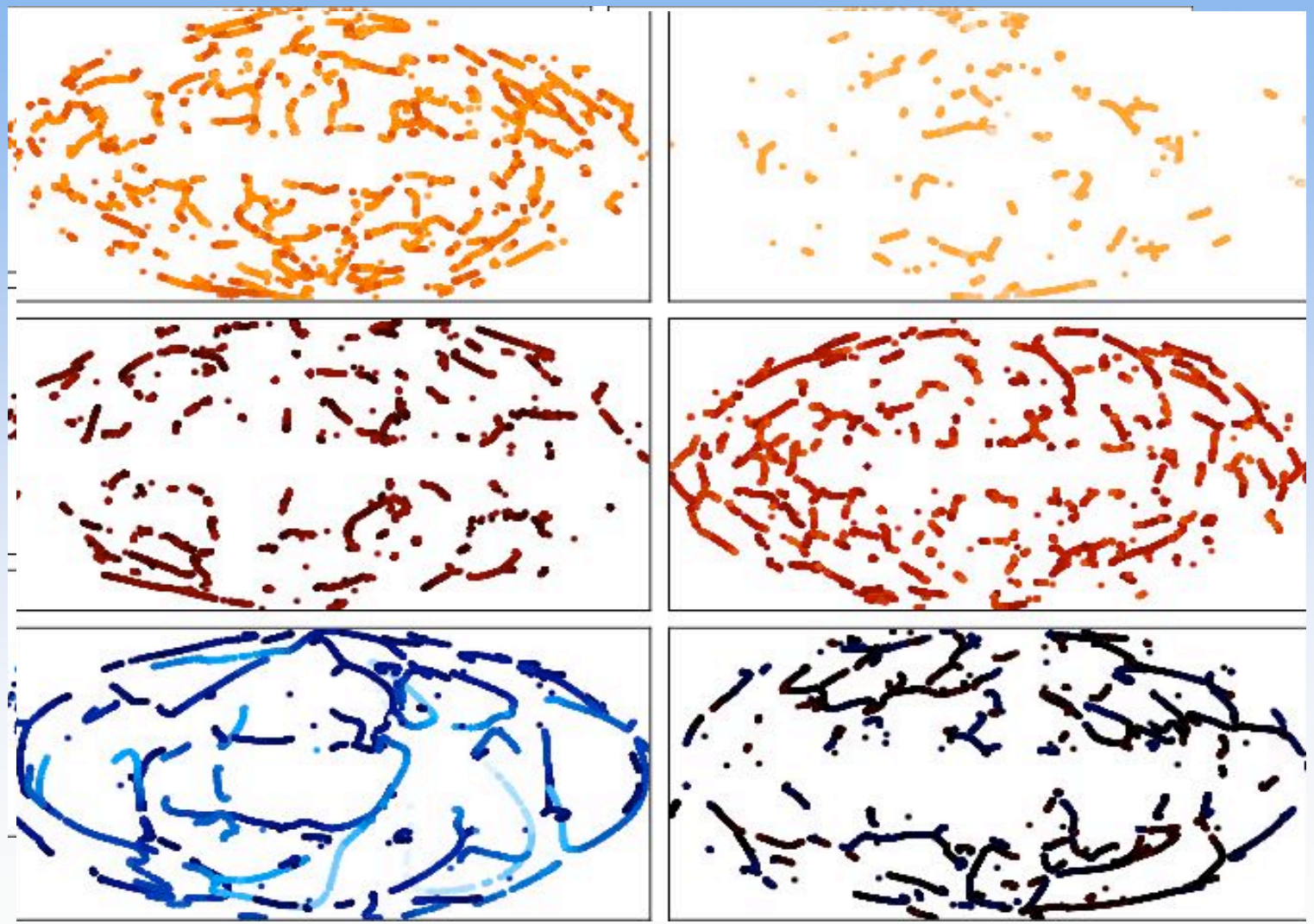
- From a density field
- Compute extrema
- Start from saddle points and follow gradient up to the maxima

In practices
noise & selection fctn

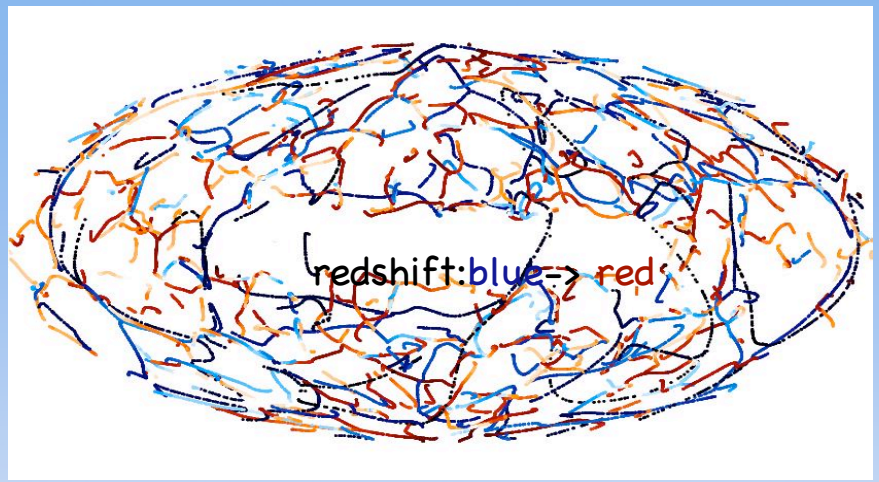


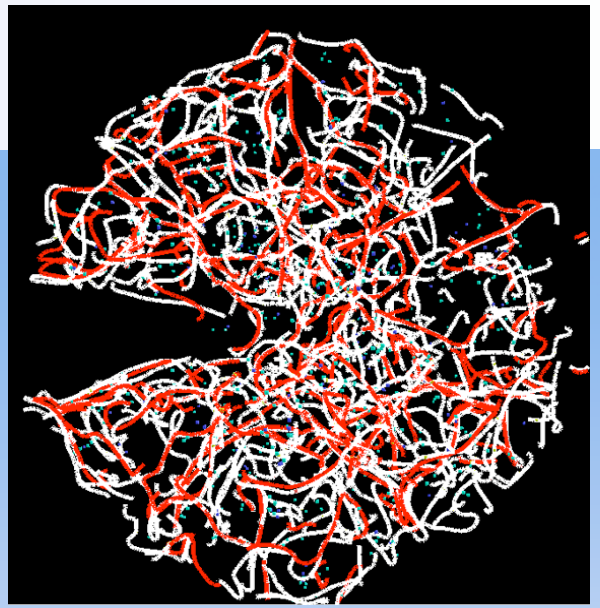

with duplicates
all critical lines
before post processing
final local skeleton

Skeleton redshift evolution with 2MASS XSCz (Jarrett)

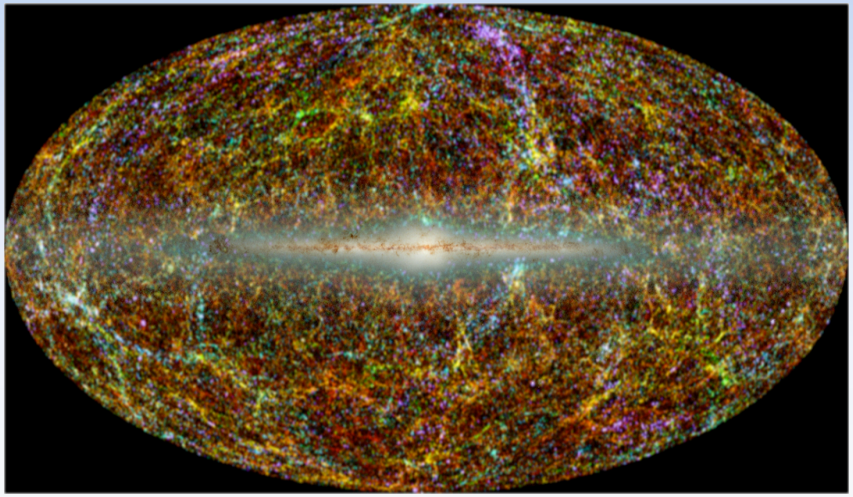


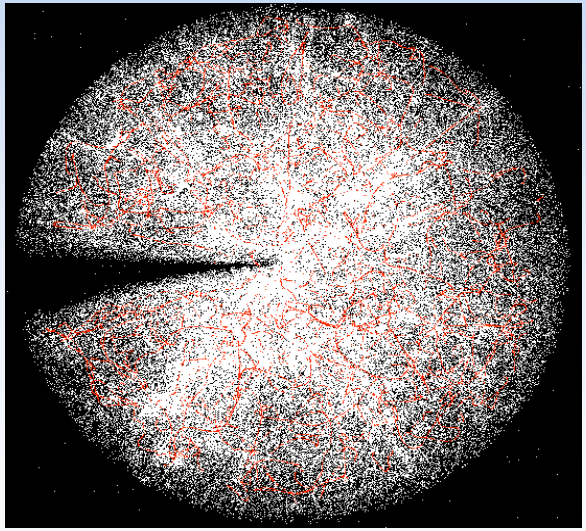
2MASS XSCz skeleton



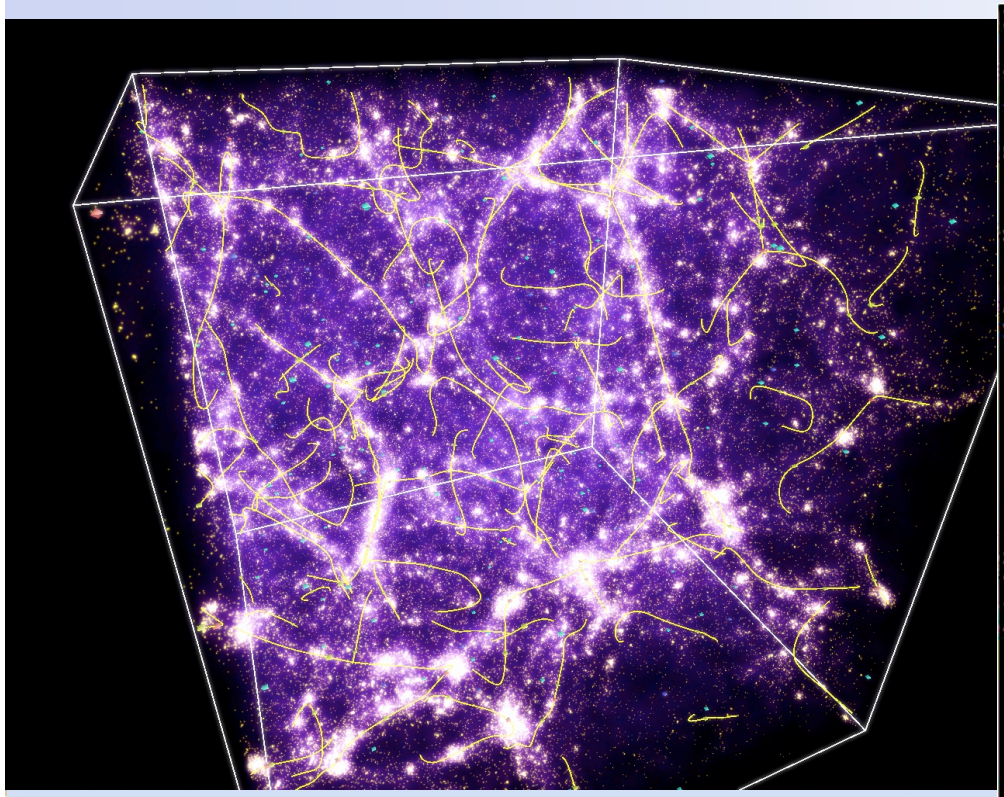


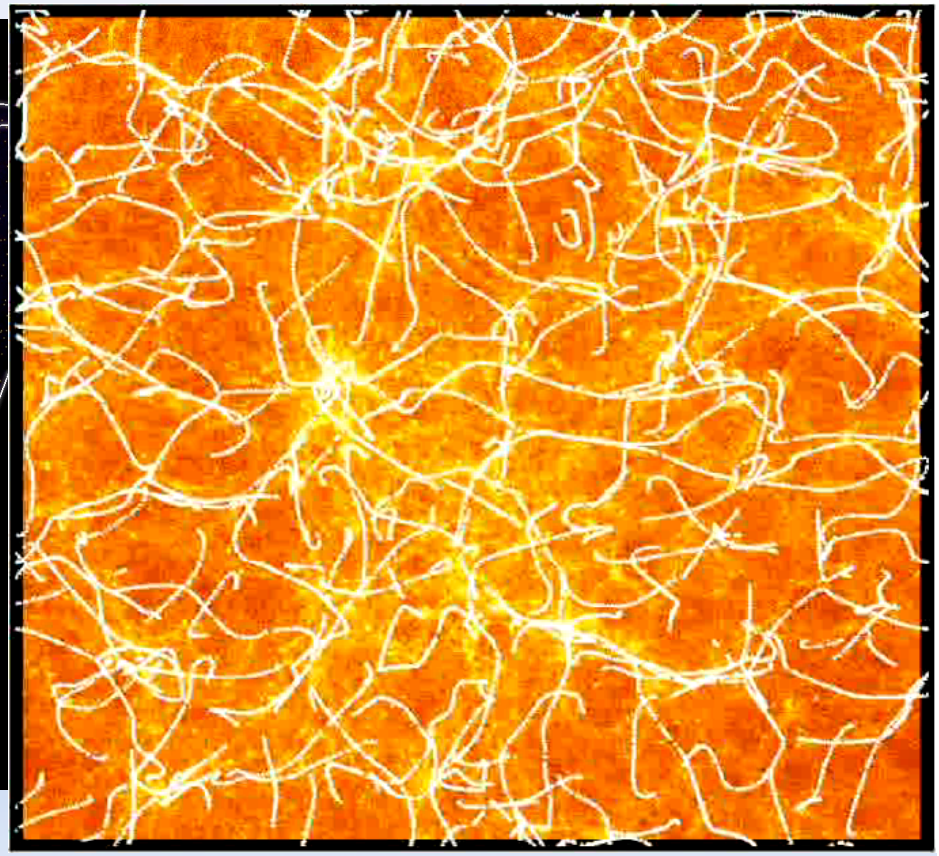
≠ smoothing lengths





2MASS XSCz data



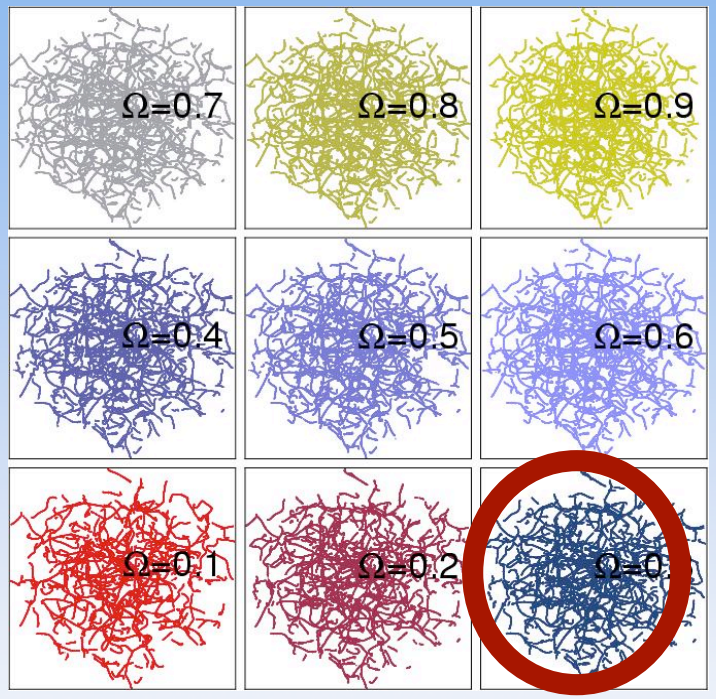


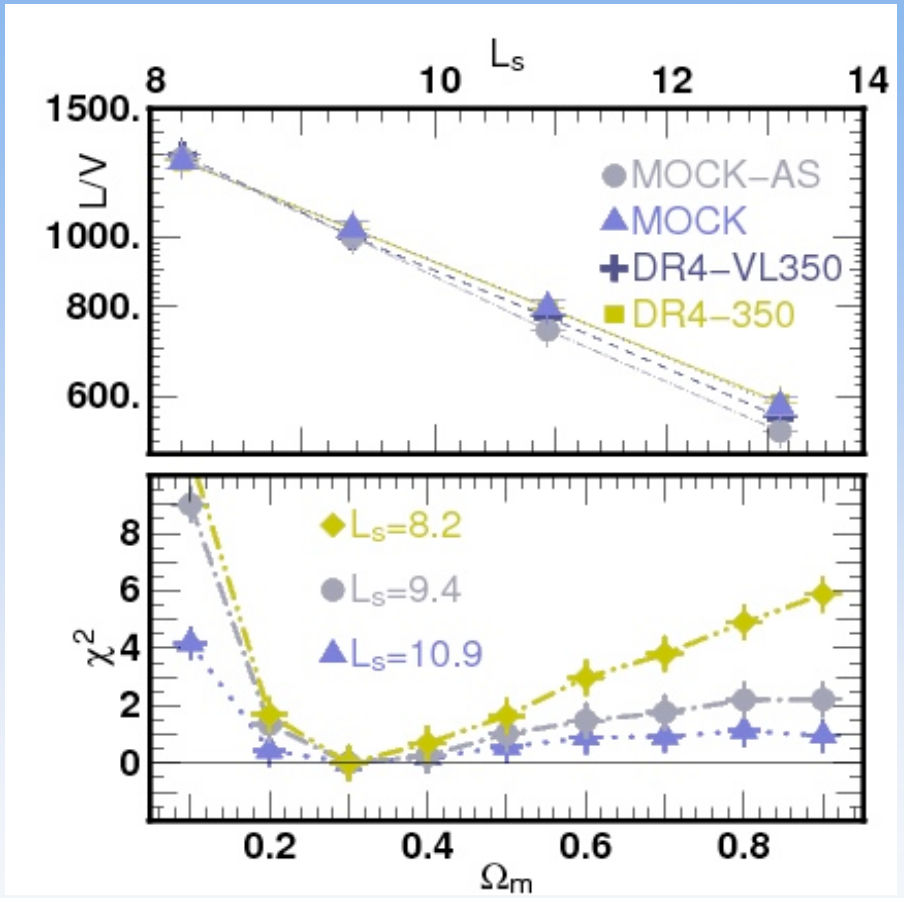
$V_{obs} = V_{expansion} + V_{masses}$

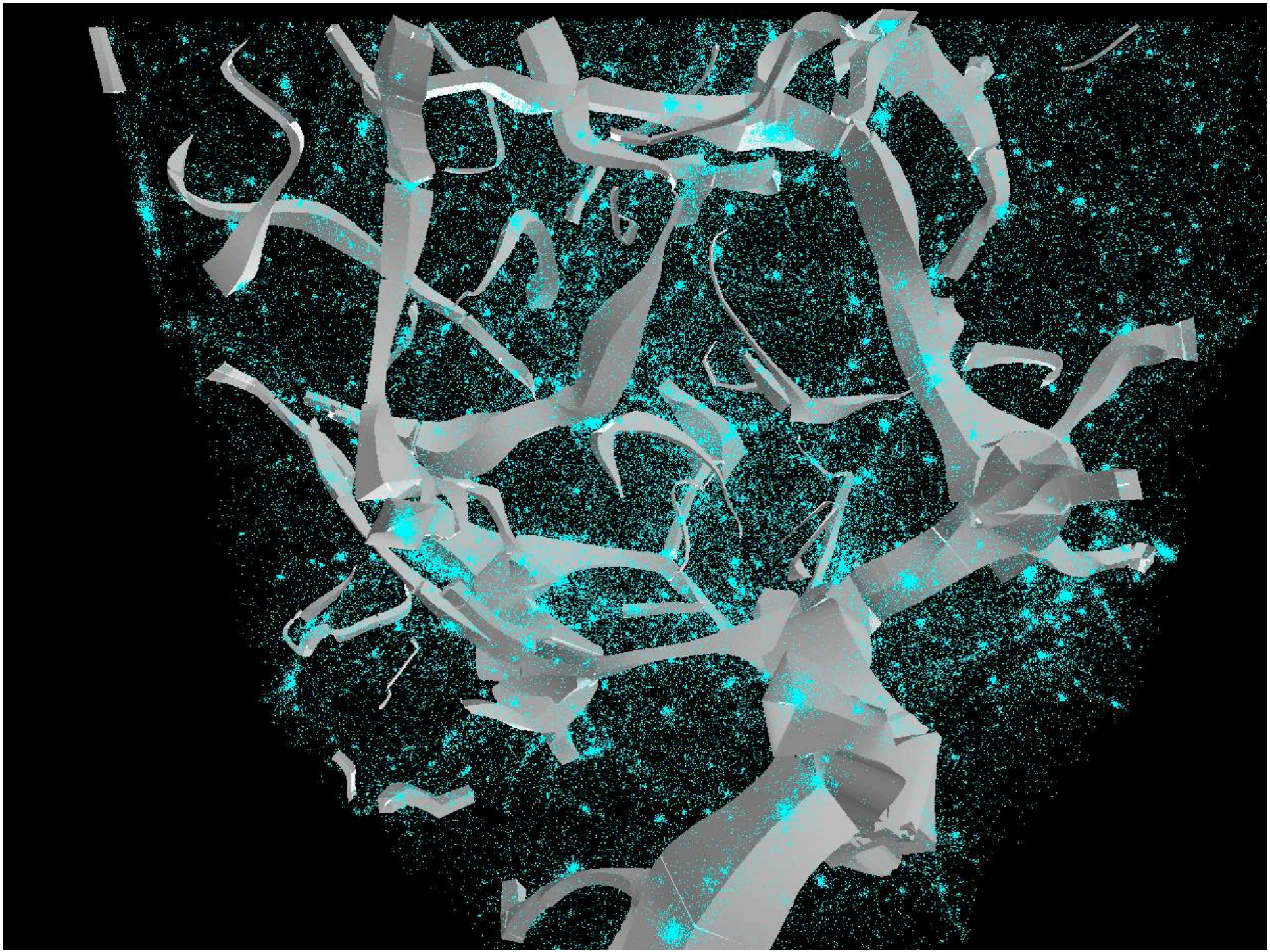
$V_{expansion} = H \times d$

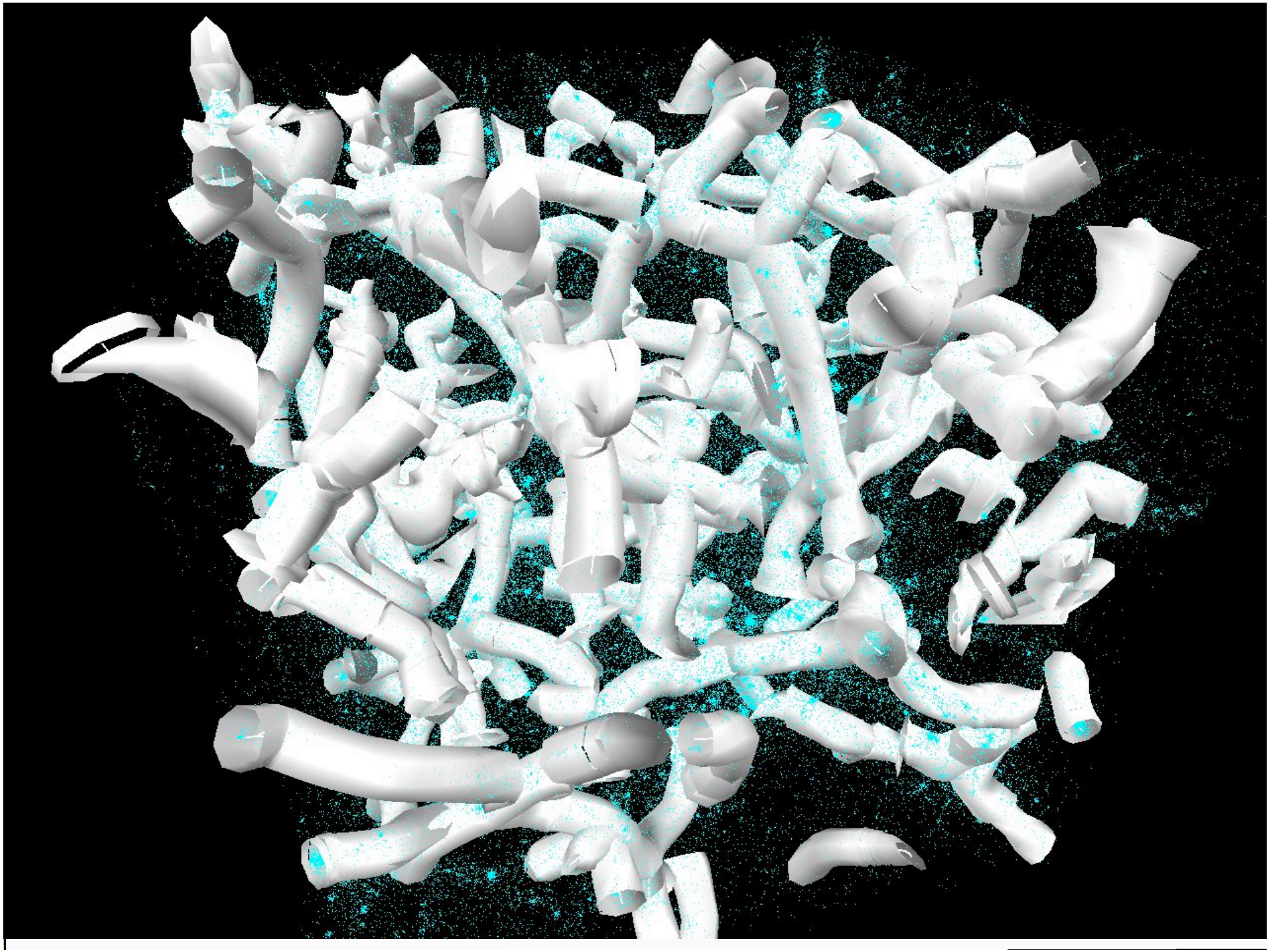
The peculiar velocities of the filaments could be driving the evolution of the structures, the galaxies external evolution, the star formation history…

Skeleton of observed galaxy structures vs simulated galaxy structures.



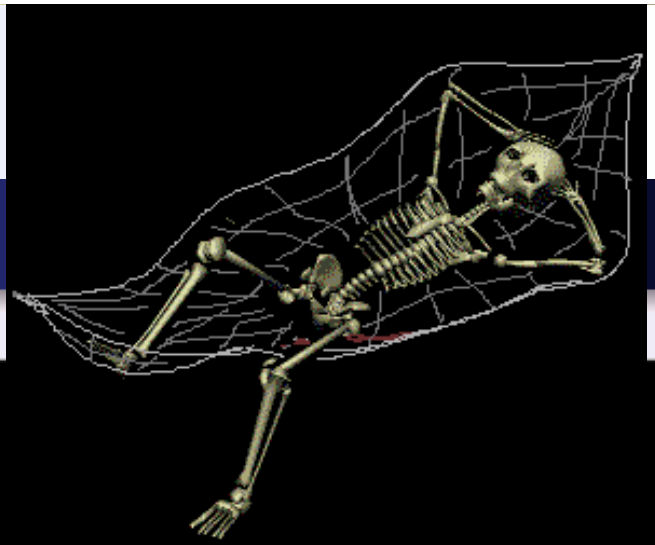


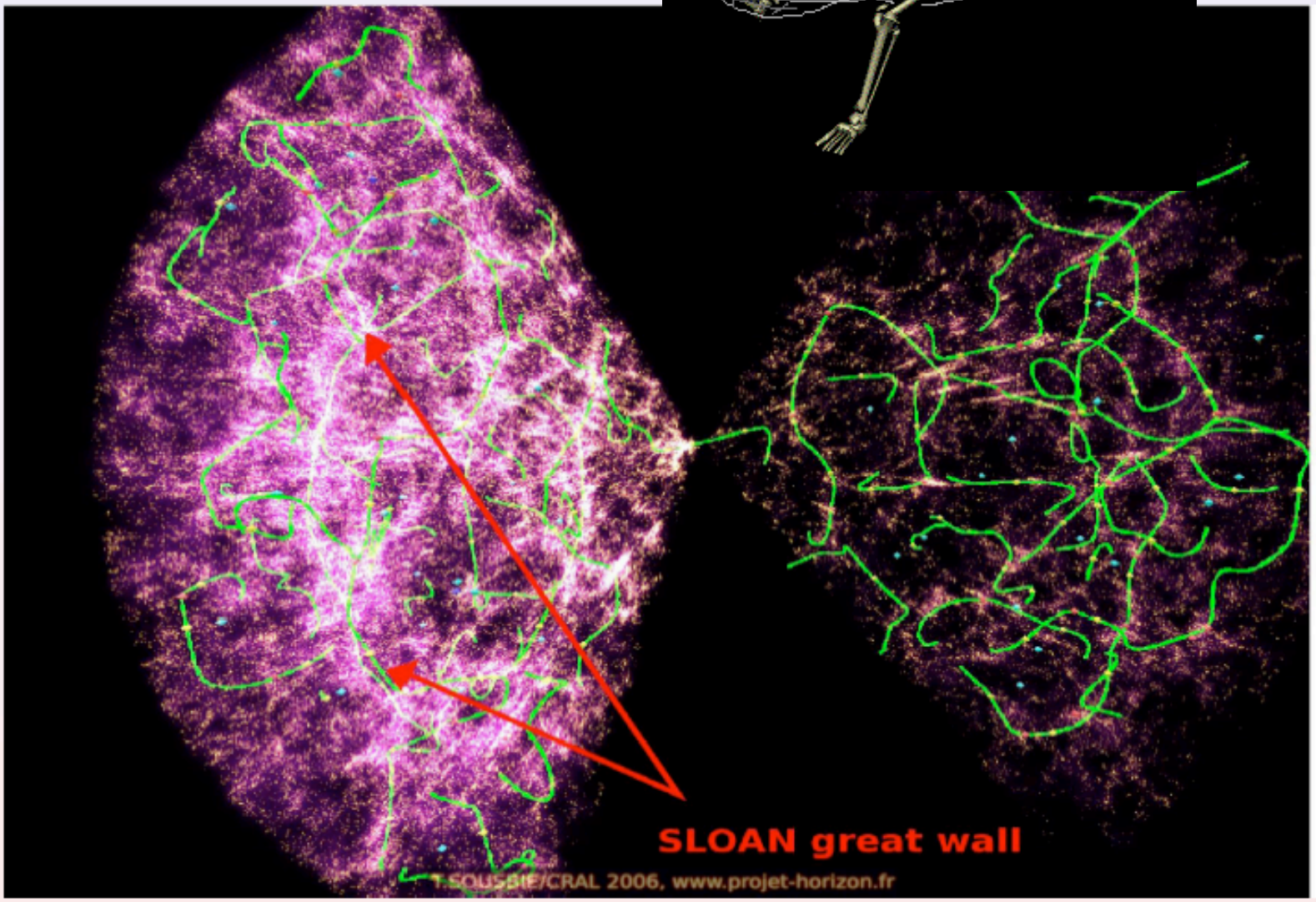


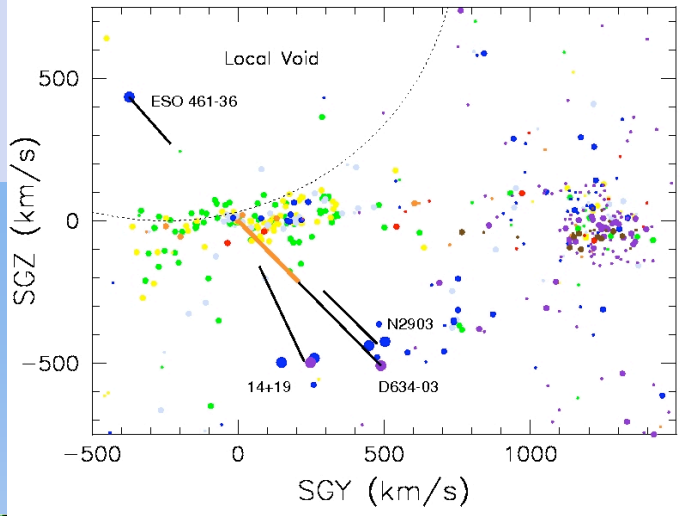


SDSS DR4

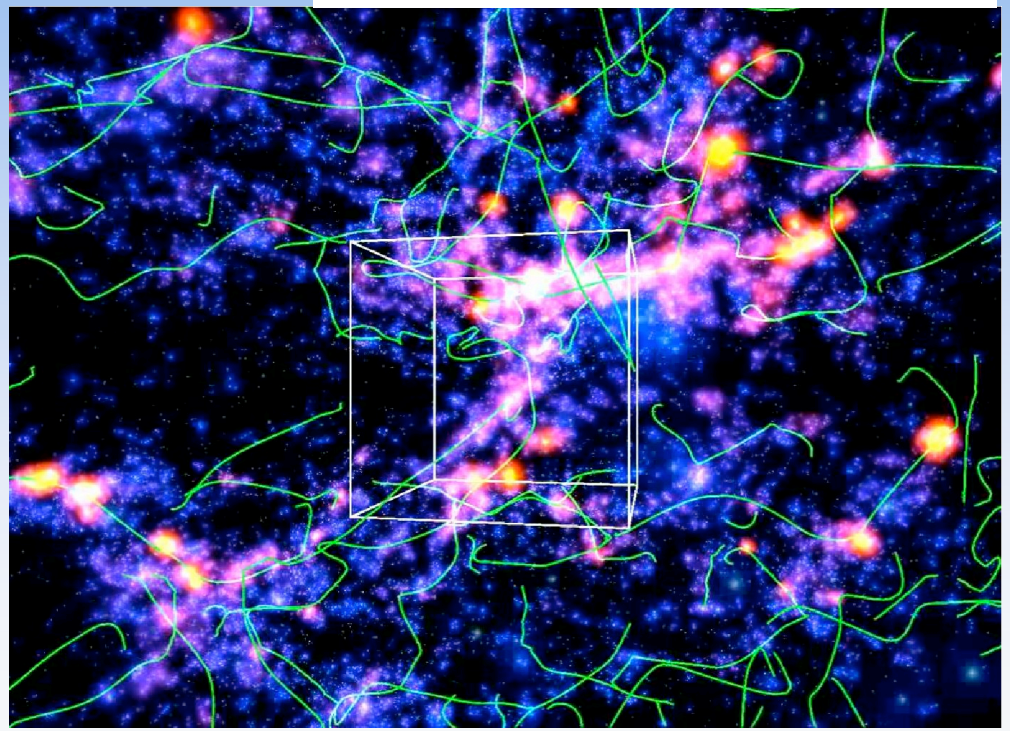
Skeleton of the SDSS



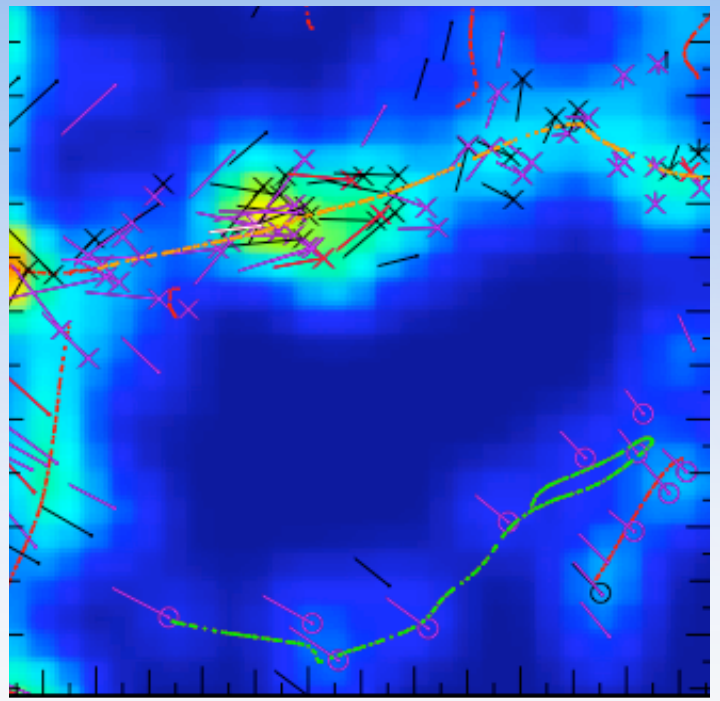




Tully, Courtois et al. 2008 ApJ 676, 184

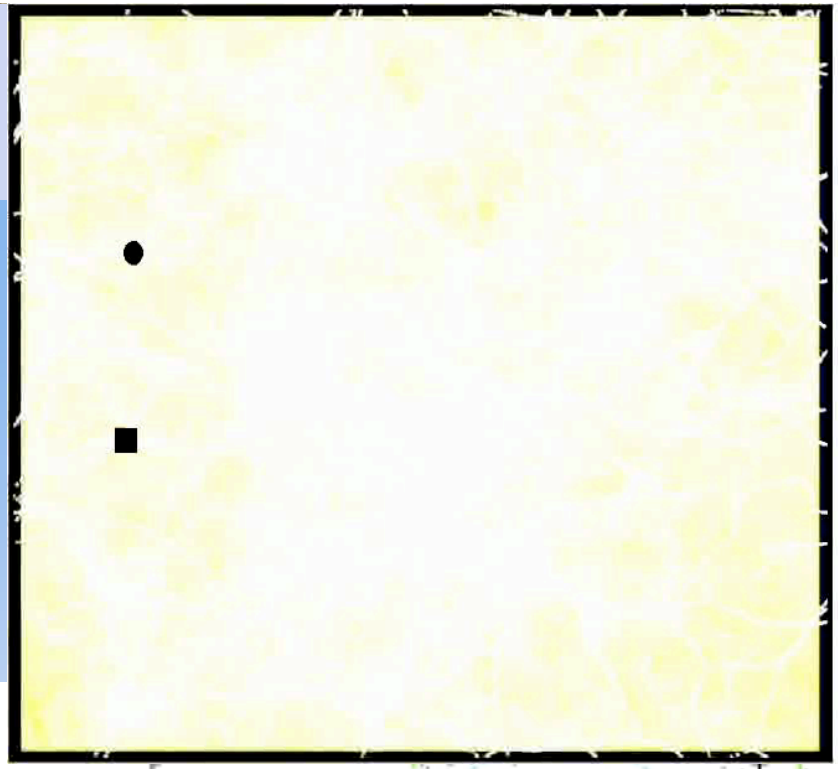


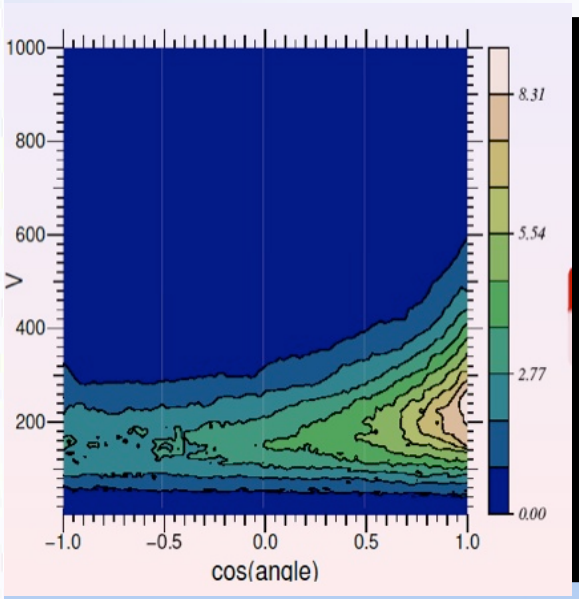
Observed local universe and its skeleton

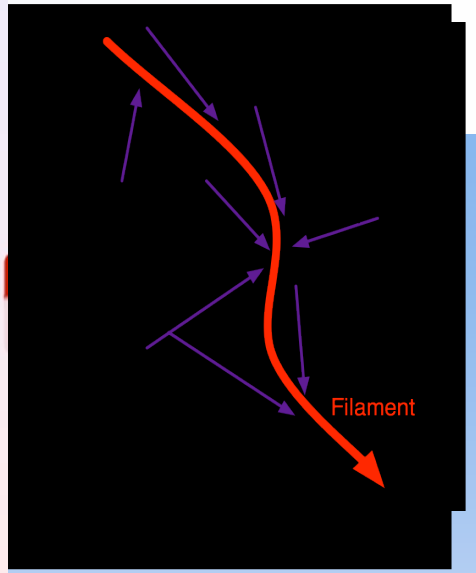


Simulated local universe and peculiar velocities

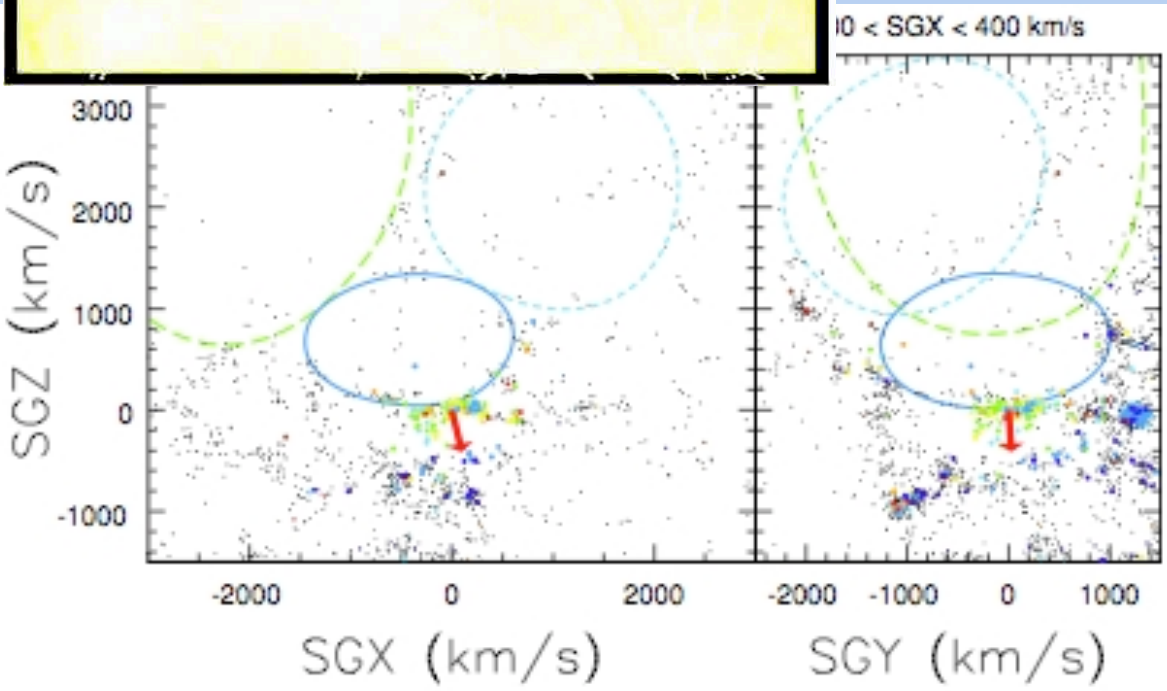
Sousbie, Courtois et al. 2009





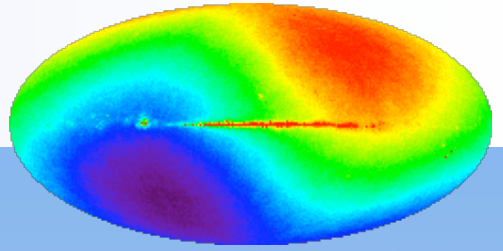


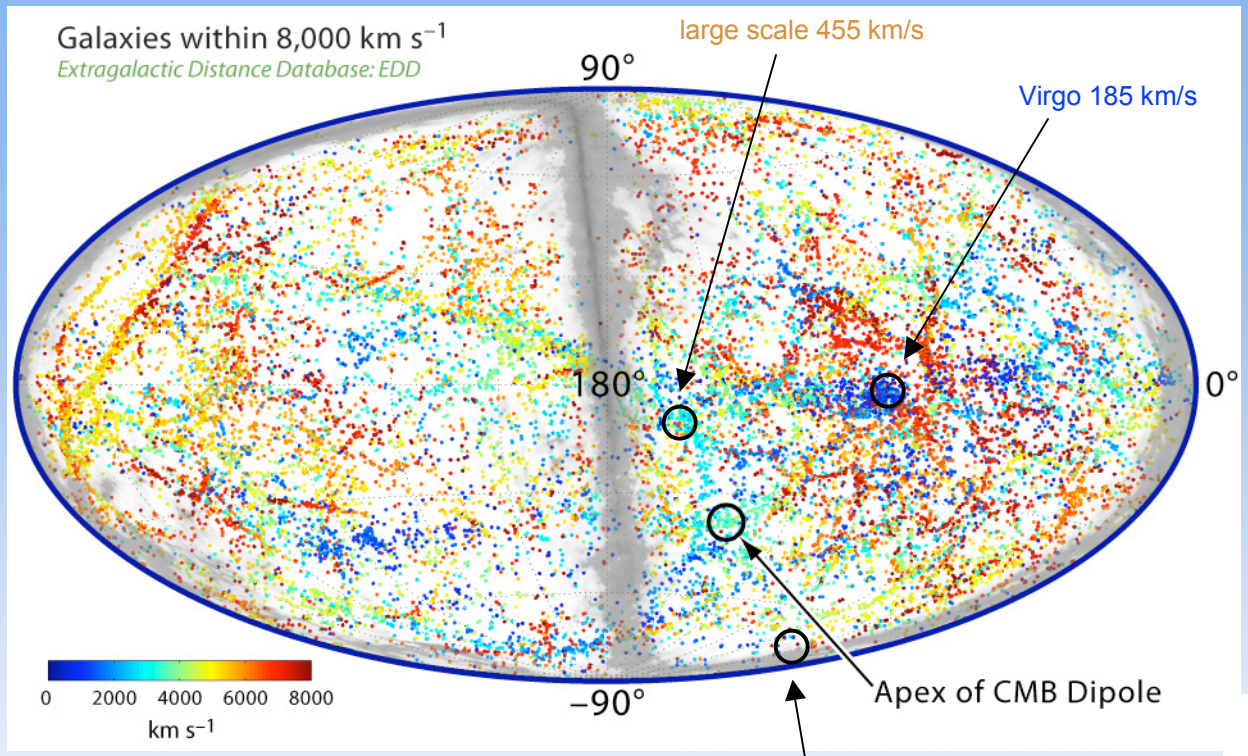
Sousbie et al. 2008, ApJ 672, 1

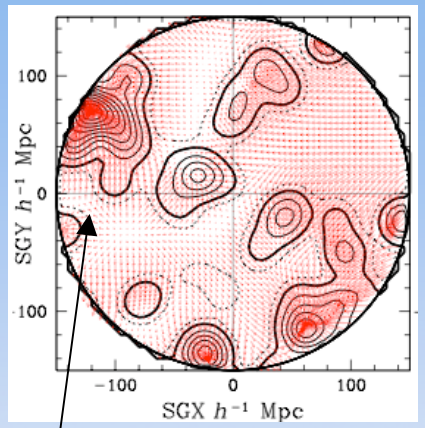


Tully et al. 2008 ApJ 676, 184

Where is the Local Sheet going?

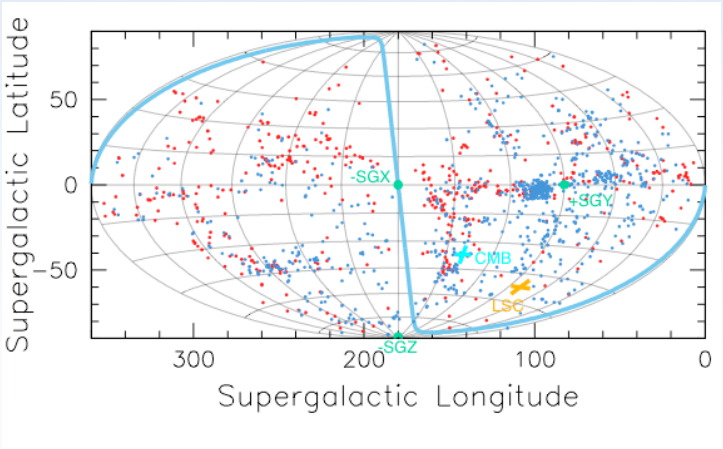


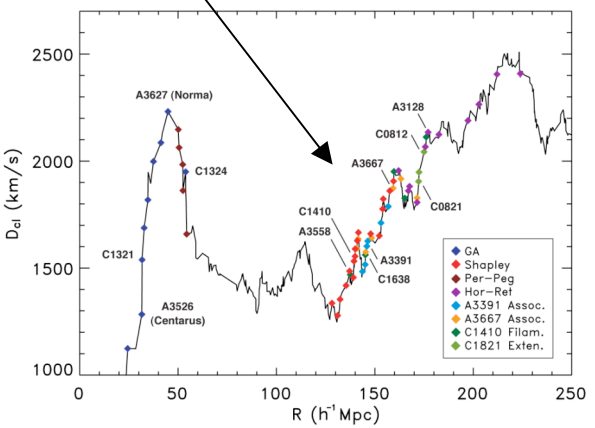




attractors on large scales

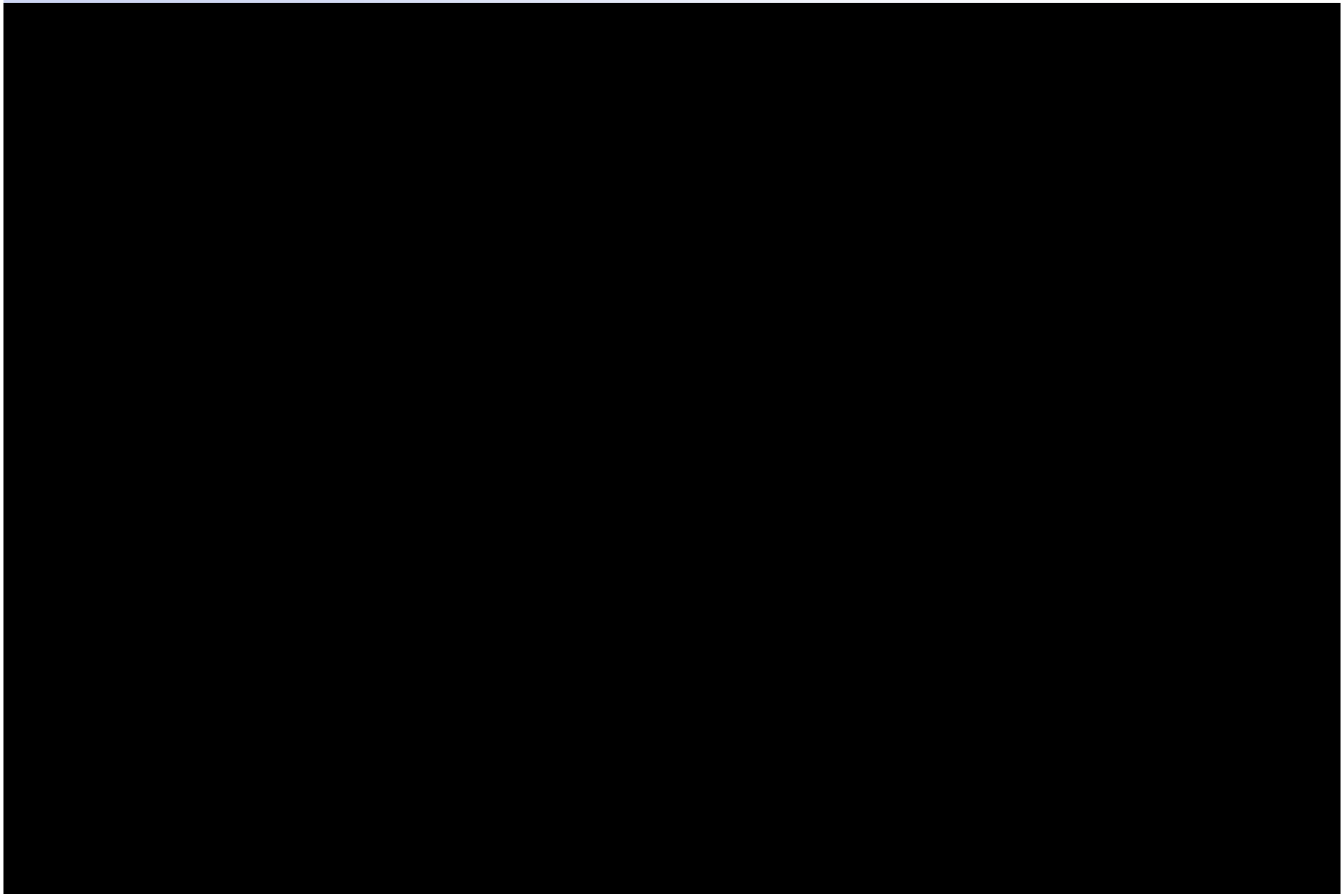
void reflex 259 km/s





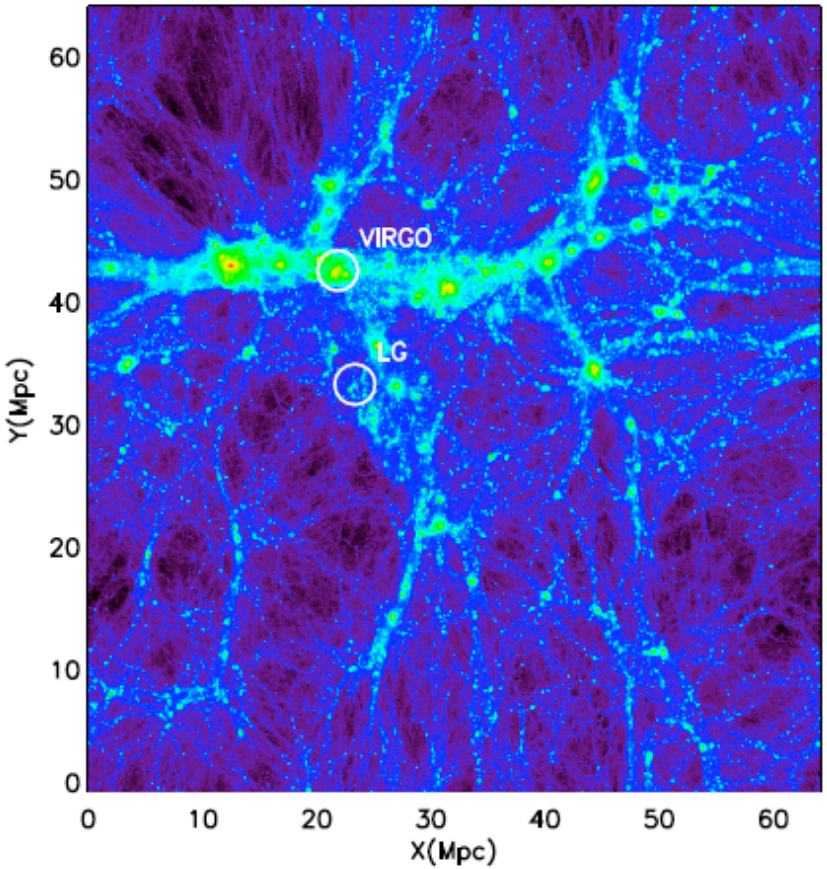
Kocevski & Ebeling 2006, ApJ, 645, 1043

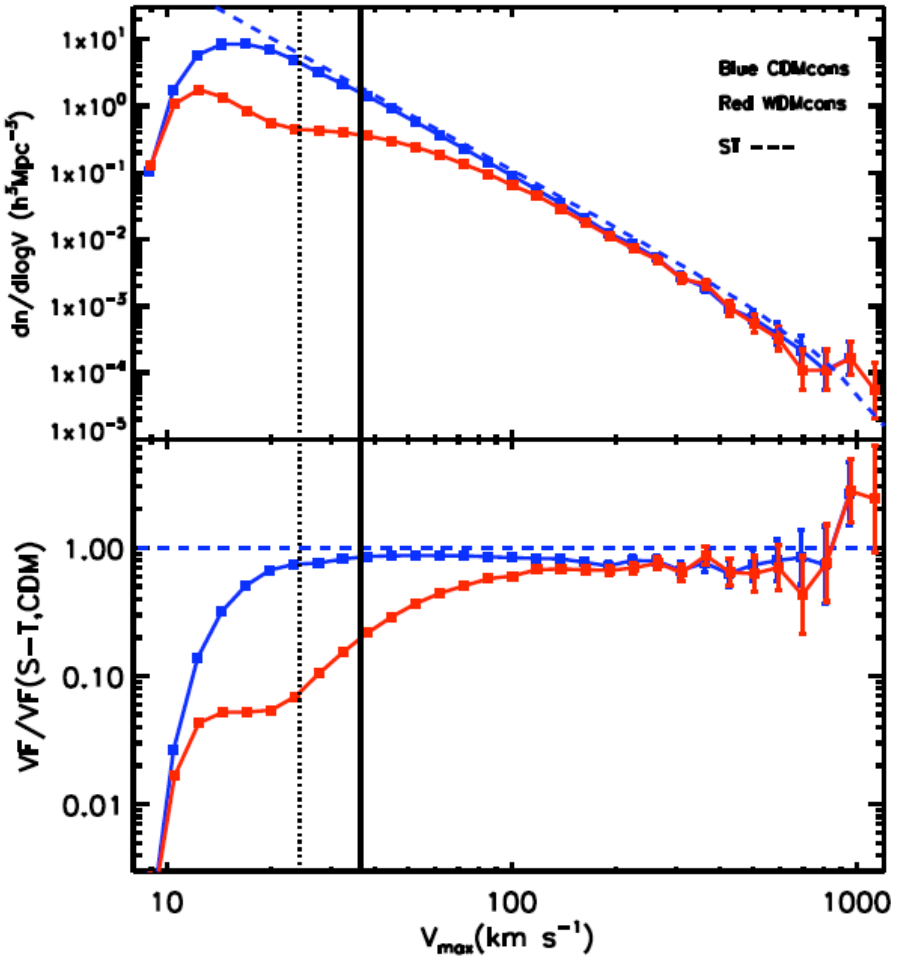
Cosmic Flows: status 2008



CDM simulations, constrained on the local universe

Zavalla et al. 2009-arxiv0906-0585

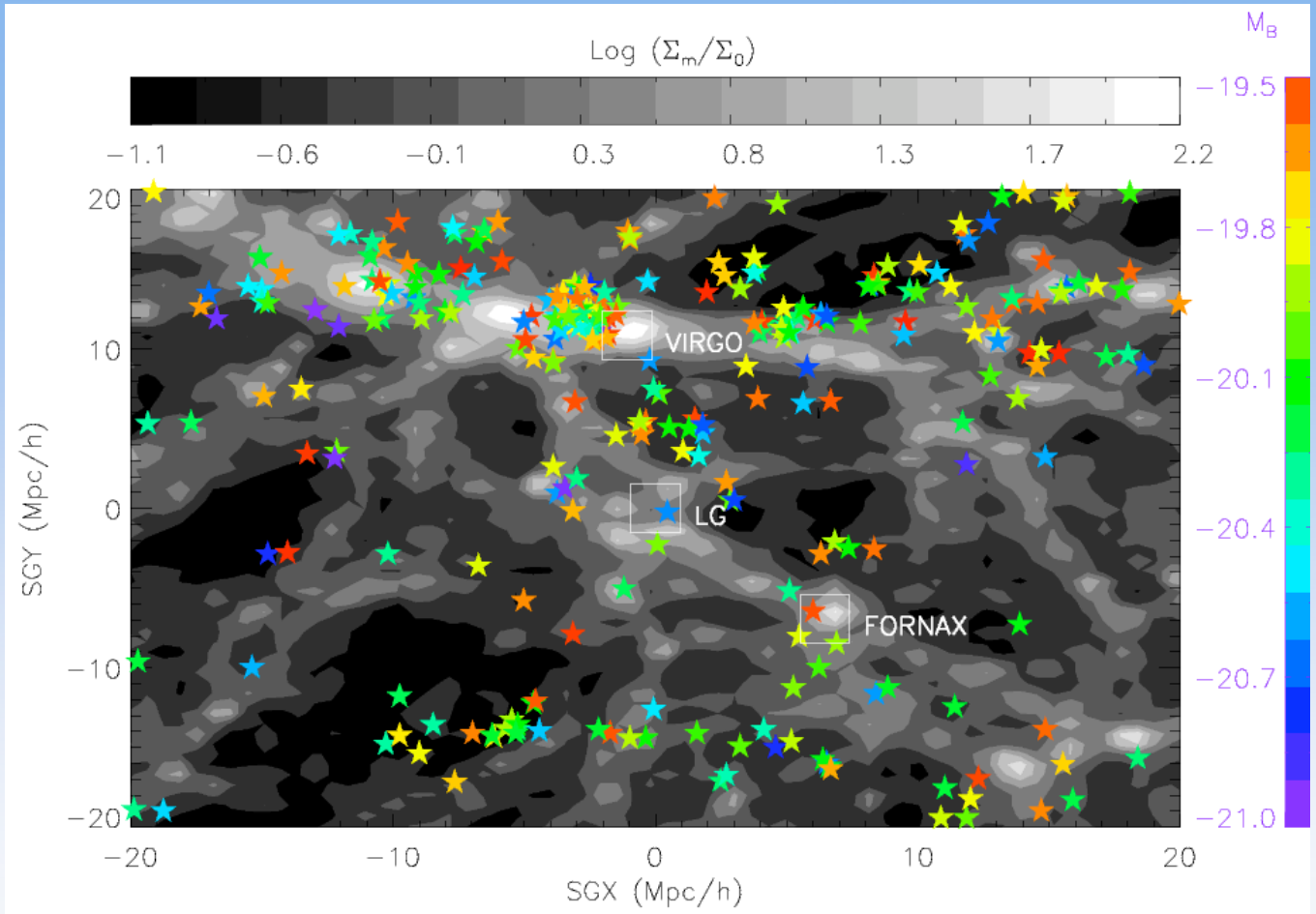




Local cosmic flows in the Local Universe with Tully et al. 2008 observational catalog

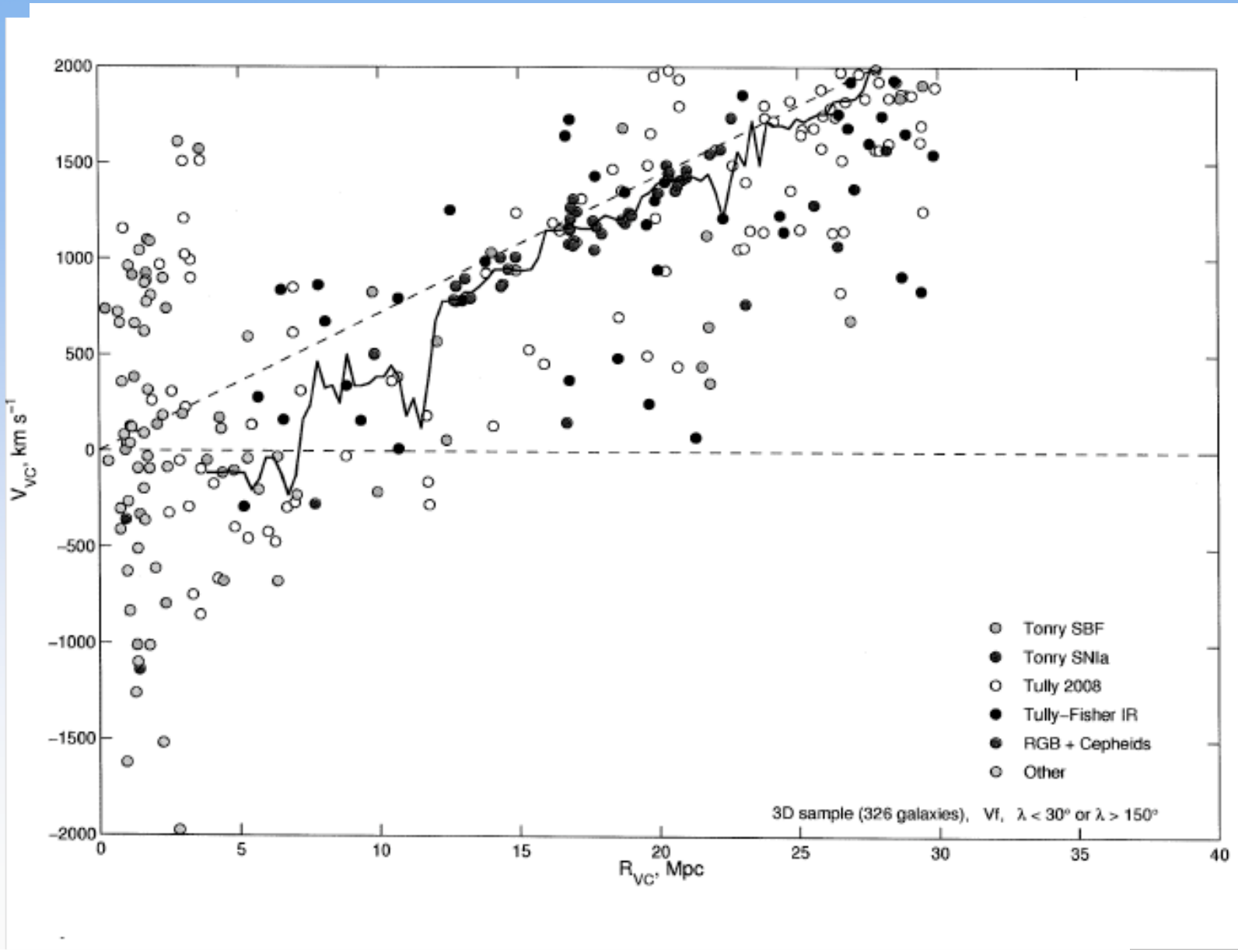
credits : Antonio Cuesta 2009

Simulations : Gottloeber, Yepes, Klypin, Hauffman 2009



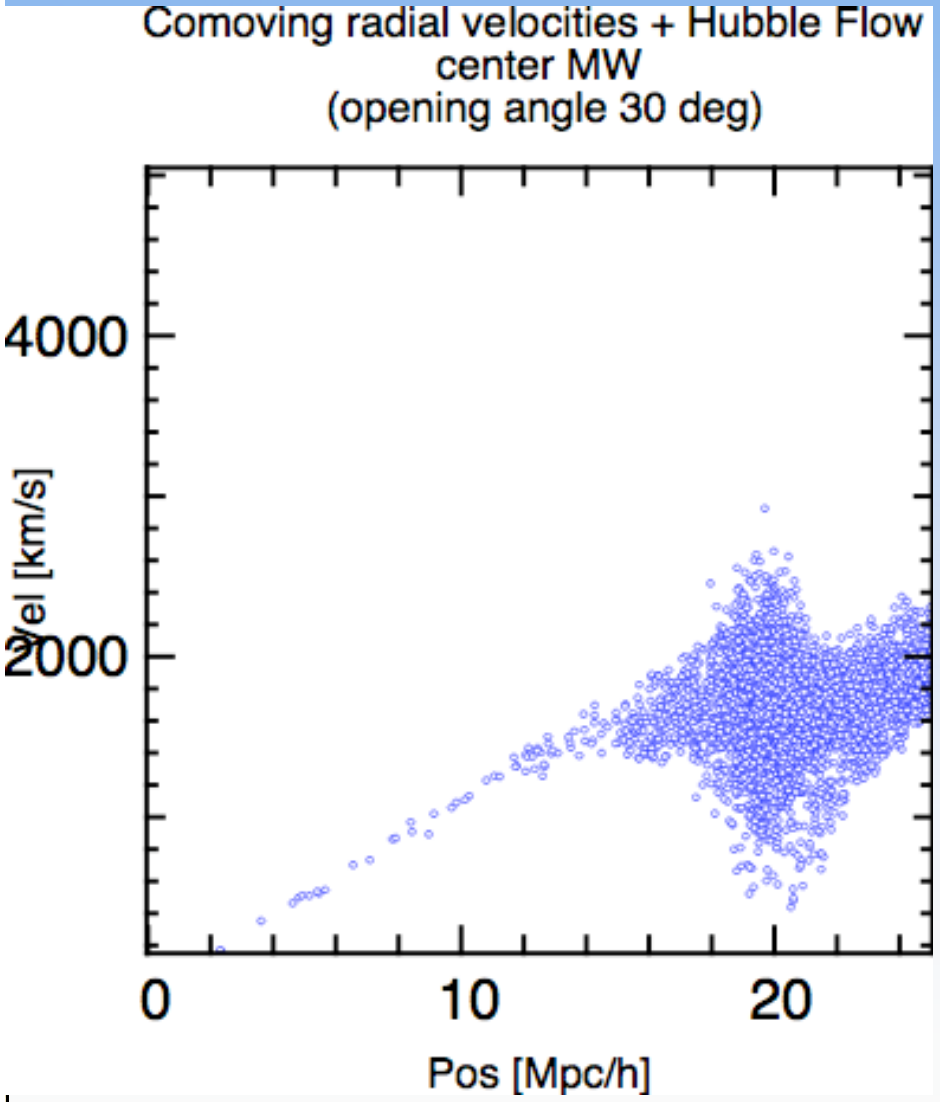
Slice of BOX64CR-WMAP5 projected from -5Mpc/h<SGZ<+5Mpc/h, shown as contours of surface density in black & white. On the top of it, Tully's et al 2008 catalog of the Local Universe is shown as stars, color-coded according to their B-band absolute magnitude.

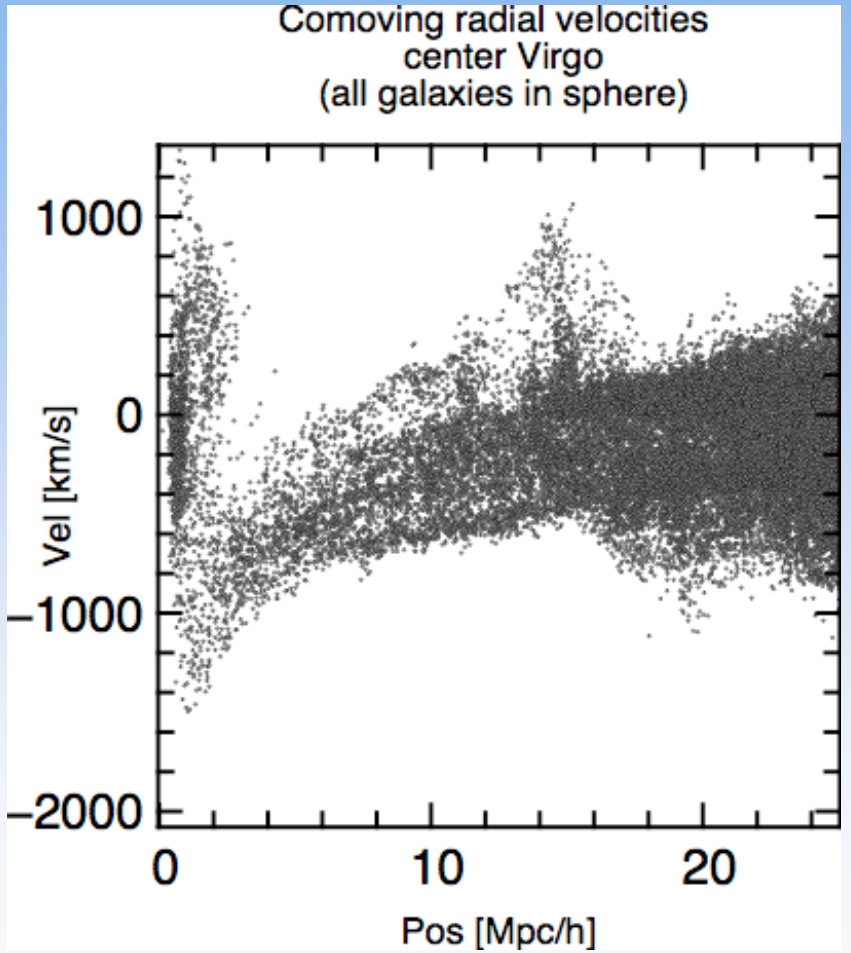
Local cosmic flows around Virgo : Karachentsev, Courtois, Tully 2009



Local cosmic flows around Virgo : Forero, Karachentsev, Courtois 2009

Simulations : Gottloeber, Yepes, Klypin, Hauffman 2009





COSFLOS Cosmic Flows

http://edd.ifa.hawaii.edu/

http://ifa.hawaii.edu/~cosmicflows

Programs currently in progress : at GBT (large program status 800 hours), Parkes, Mauna Kea, HST

- Supernovae Ia (84) - completed
- Clusters (14) about 500 galaxies - 98% completed
- Zero point calibrators about 35 (Cepheids/TRGB) - completed
- Optical selected sample at 3,000km/s: 1,500 galaxies (HI completed, I band)
- Near IR selected sample at 6,000km/s: 1,500 galaxies (HI 98%, I and K band)

Current Digital archive :

9,000 galaxies from Arecibo, GB140, GB300, Effelsberg, Nancay

+ 3,000 Nancay +2,000 GBT +1,000 ALFALFA +1,000 PARKES

--> 16,000 profiles for 12,500 galaxies

COSFLOS Cosmic Flows + **CLUES** Constrainted Local UniversE Simulations

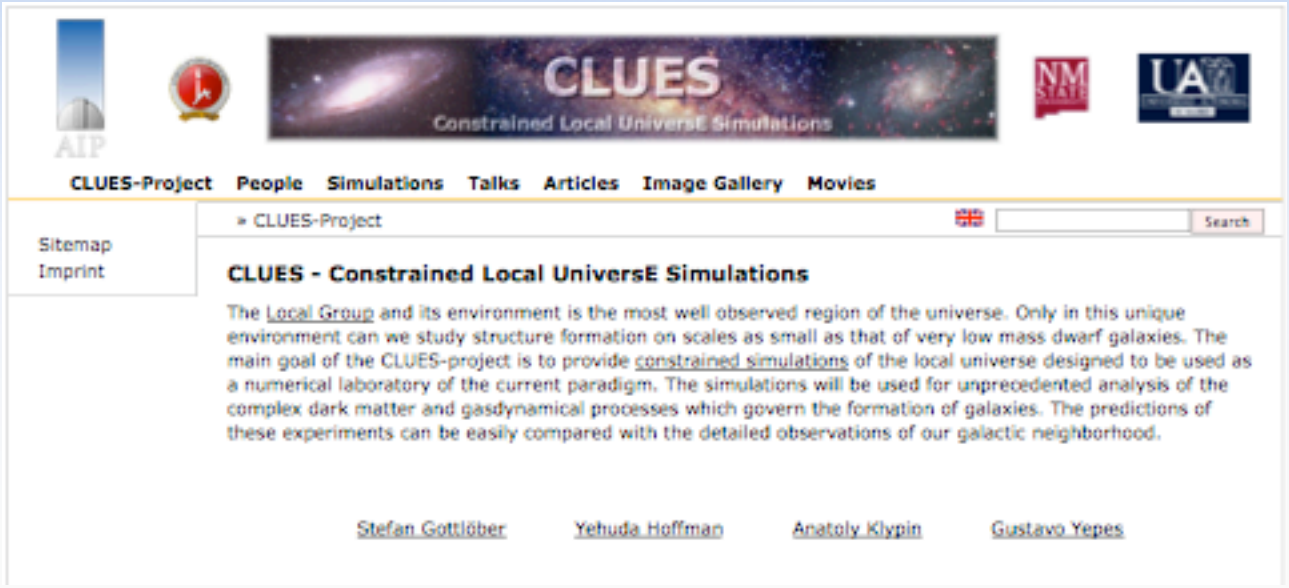
http://edd.ifa.hawaii.edu/ , http://ifa.hawaii.edu/~cosmicflows

\+ http://www.clues-project.org/

Status analysis : Tully et al. 2008: 1,800 distance measurements
In the local universe: less than 10% errors on distances :
measure a peculiar velocity 260+/- 25 km/s away from the Local Void.

Current analysis 2009-2010: X2 depth, X2 number density grid of distance measurements all sky

Year 2011-2014 : PanSTARRS-SKYMAPPER photometry : error bar/2 on the peculiar velocity
Dwarf Galaxies new distances HST ACS data + new HI surveys Flat Galaxies



Thanks to all the hard work in the collaboration :

Tully, Fisher, Rizzi, Karachentsev, Shaya, Makarov, Bonhomme, Forero, Sousbie, Gottloeber, Kraan-Korteweg, Koribalski, et al.

Thanks for your attention !