

Statistics for large cosmological surveys

Enn Saar, Tartu Observatory

ESS20, 27.09.2012

Sloan Legacy Survey (SDSS DR7)

8400 square degrees (1/5 of sky)

230 million objects

spectra of 930000 galaxies, 120000 QSO,

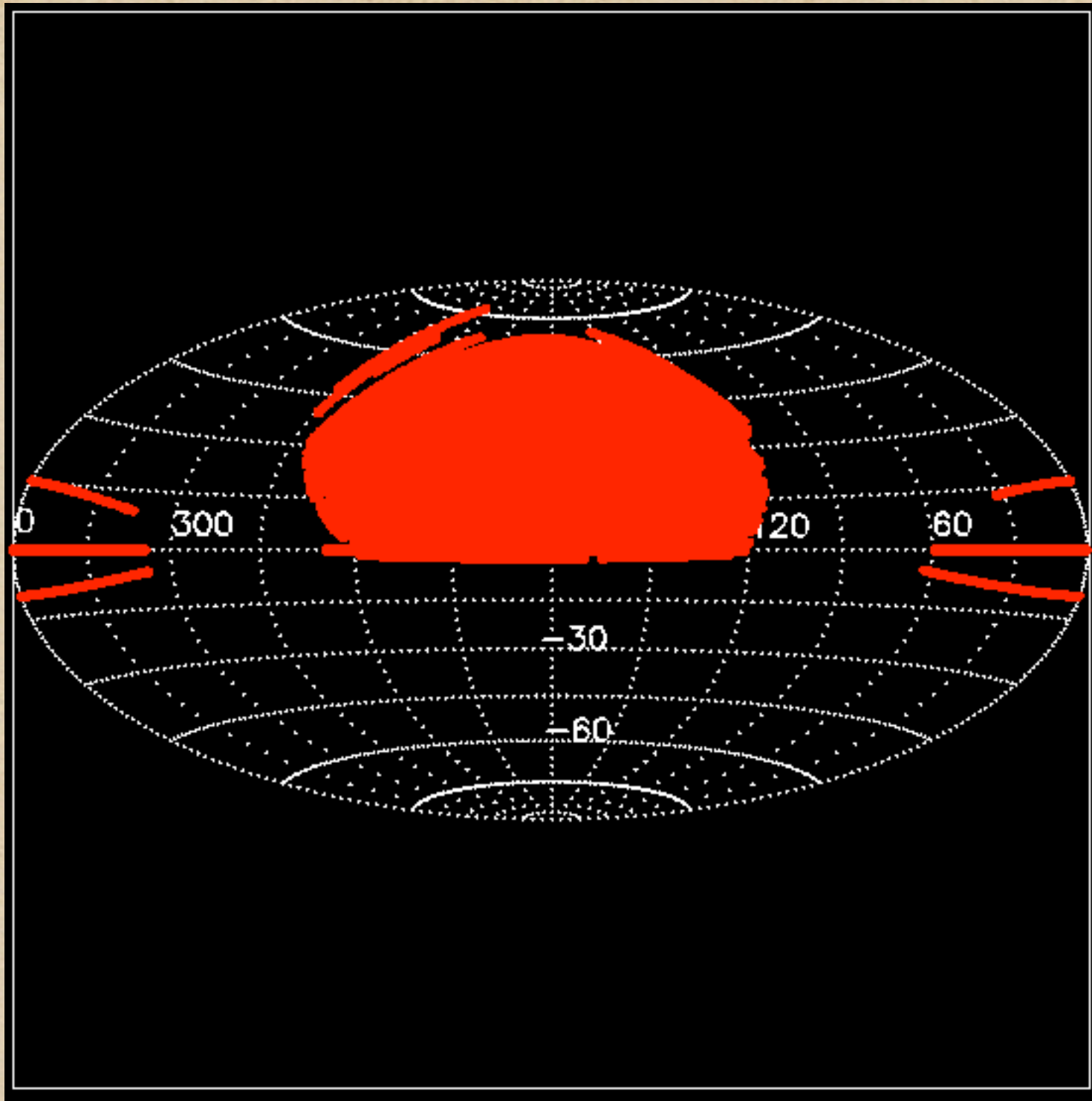
225000 stars

Apache Observatory 2.5 m telescope

8 years, team of about 200

120 Mpix camera, 600 fibers per plate





SDSS DR7 footprint



Photometry

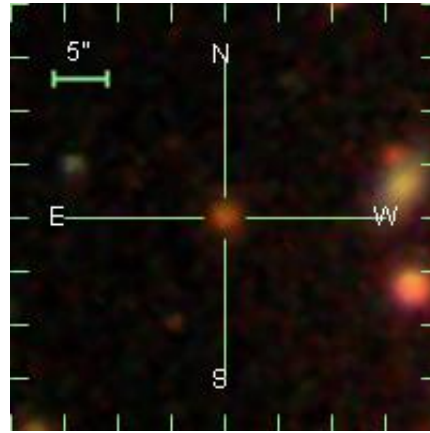
Summary data for: SDSS J082749.75+445208.5

Position Data (How do I find it?)

Object ID (objID):	Right ascension (ra):	Declination (dec):
1237654386268439267	126.95733174	44.86903116

Image Data (What does it look like?)

Preview image (click to go to Navigate tool)



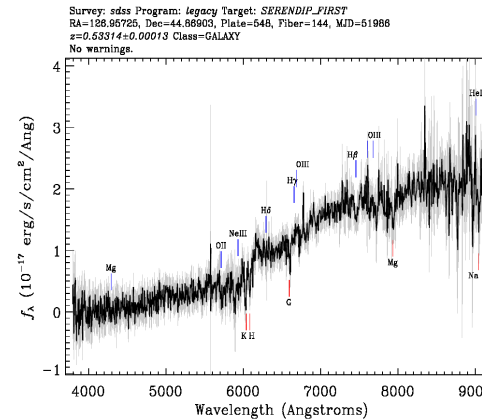
Object Type (type): GALAXY

Magnitudes:

Ultraviolet (u):	26.10 ± 0.53
Green (g):	22.50 ± 0.19
Red (r):	20.52 ± 0.04
Infrared - 7600 Å (i):	19.55 ± 0.03
Infrared - 9100 Å (z):	19.07 ± 0.07

Spectrum Data (What does its spectrum look like?)

Preview spectrum (click for a larger version)



[Interactive spectrum](#)

Spectral classification (Class): GALAXY

Redshift Data:

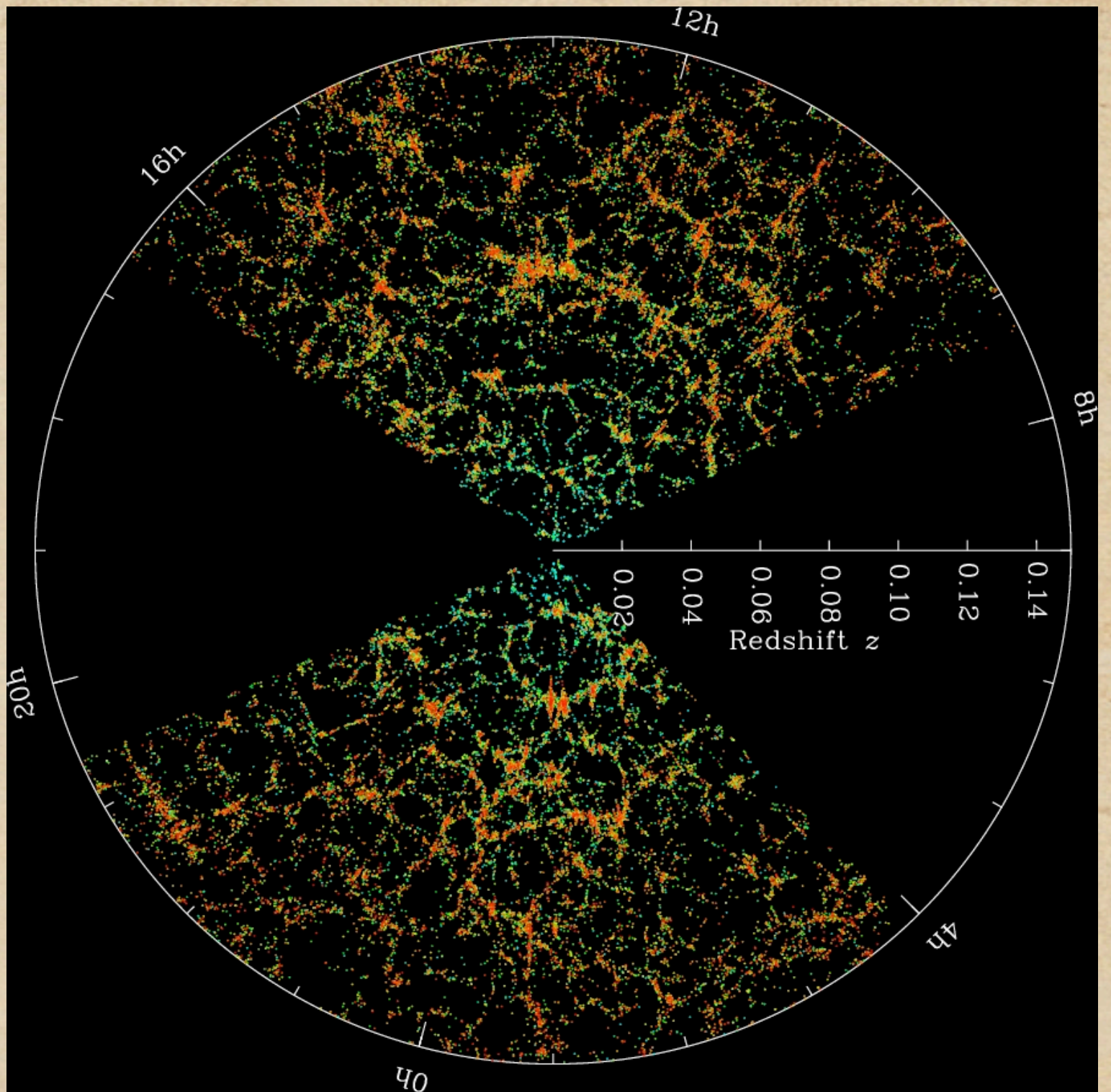
Redshift (z): 0.533137

[Get spectrum as CSV](#)

14 Tbytes of data

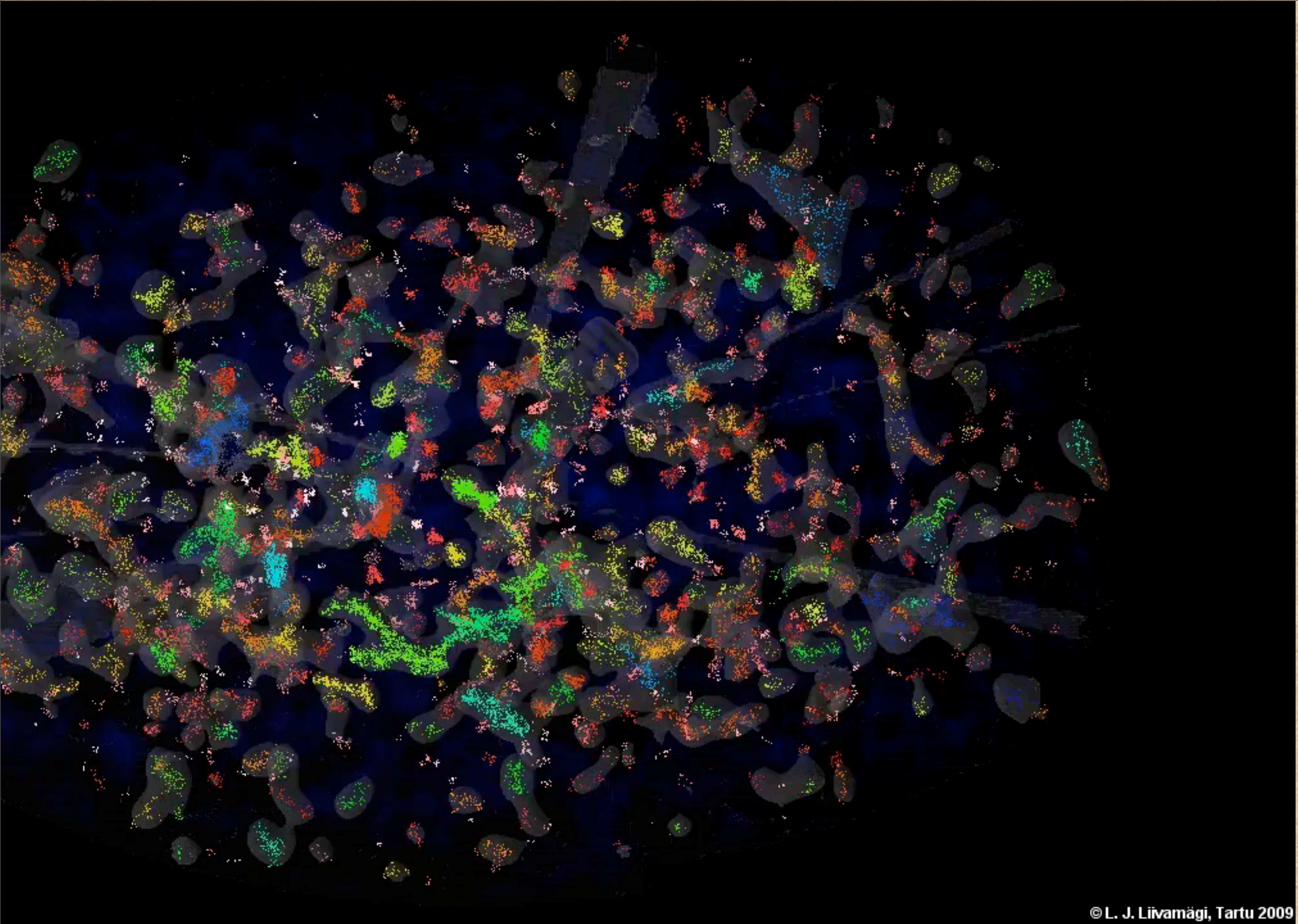
~300 table entries per object

2-D map



$$\frac{a_0}{a} = 1 + z$$

$$D = 4225 z \text{ Mpc} = 1.39 \cdot 10^{10} z \text{ ly} = 1.3 \cdot 10^{23} z \text{ km}$$



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3-D supercluster map

SDSS3 - BOSS, 1 billion spectra

Skymapper -- 1 billion galaxies, full Southern sky

Pan-STARRS -- 30,000 sq deg, North, NEO

WISE -- full-sky infrared data, 1 billion objects

DES -- 300,000 distant galaxies

GAIA -- 1 billion stars, proper motions (5 years)

Large Synoptic Survey Telescope - 15 TB/day, 10 years

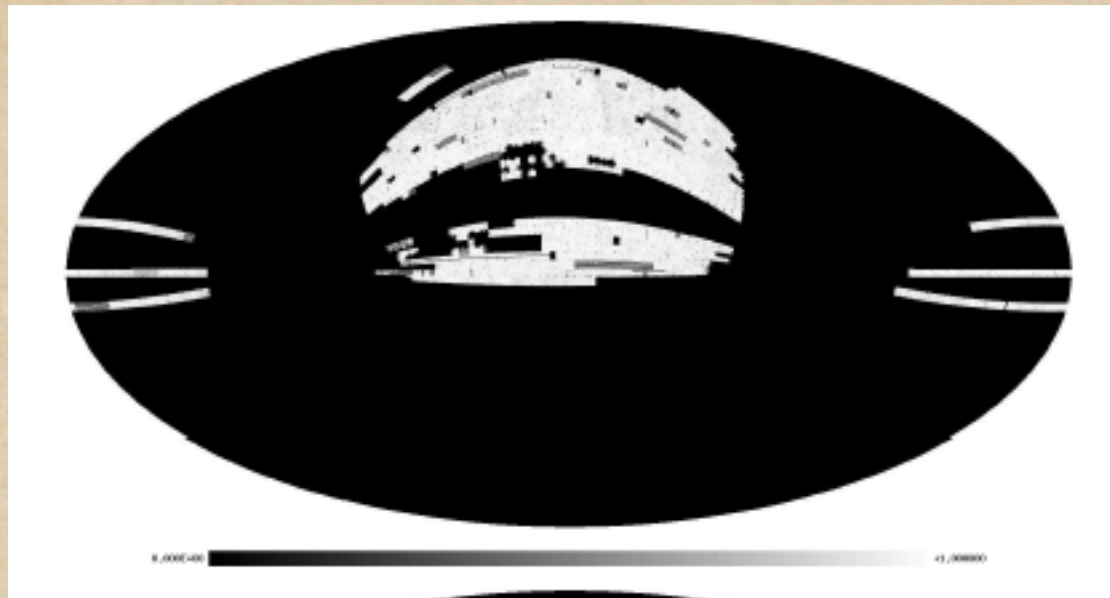
Planck mission (CMB) -- 4 PB total, 3.5 years

Virtual observatories

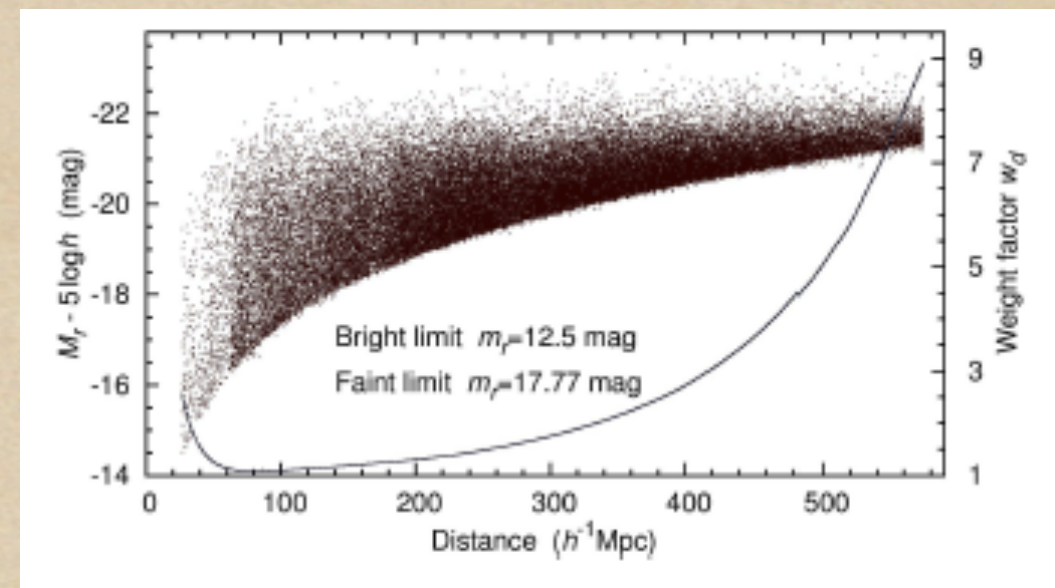
Simulations -- numerical Universes

Cosmic variance

Incompleteness factors

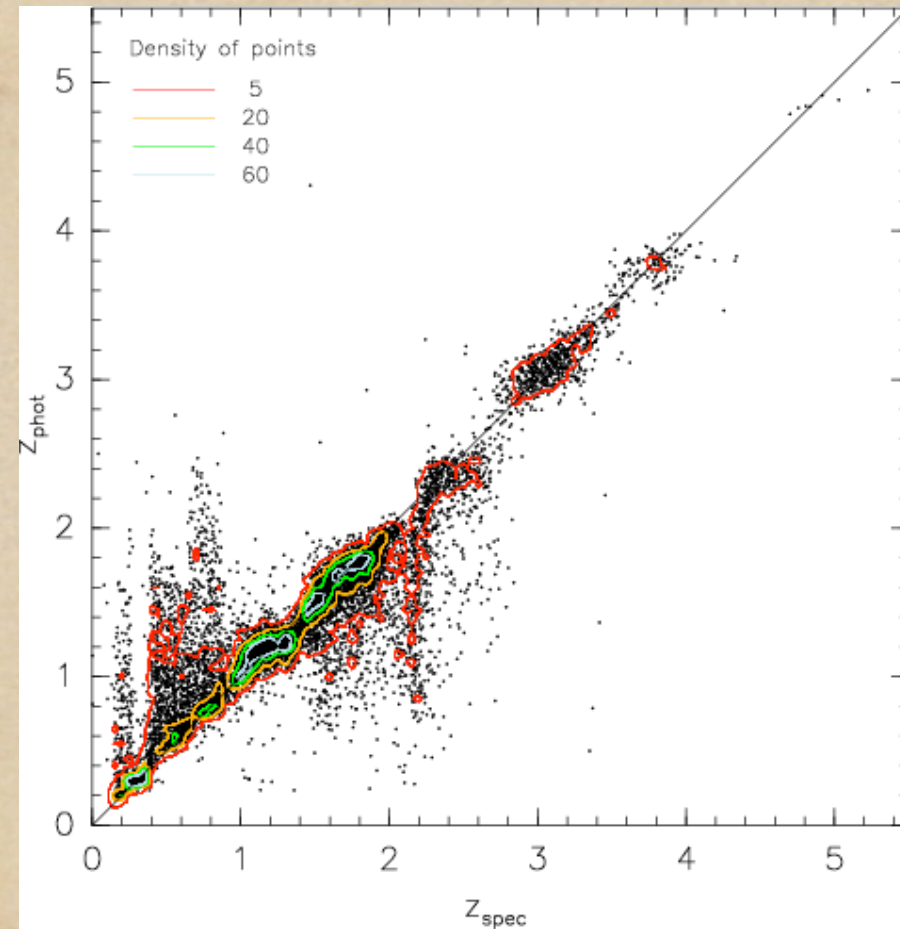
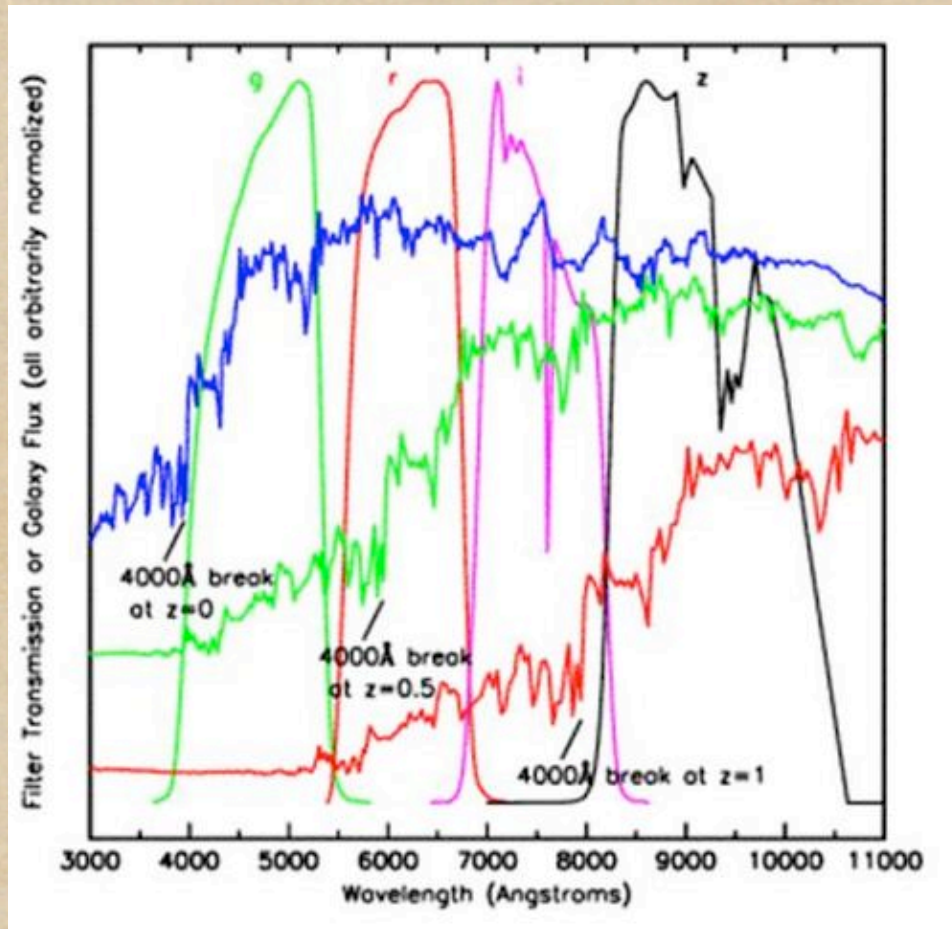


Spectroscopic



Magnitude limits

Example 1: Fighting photo-z

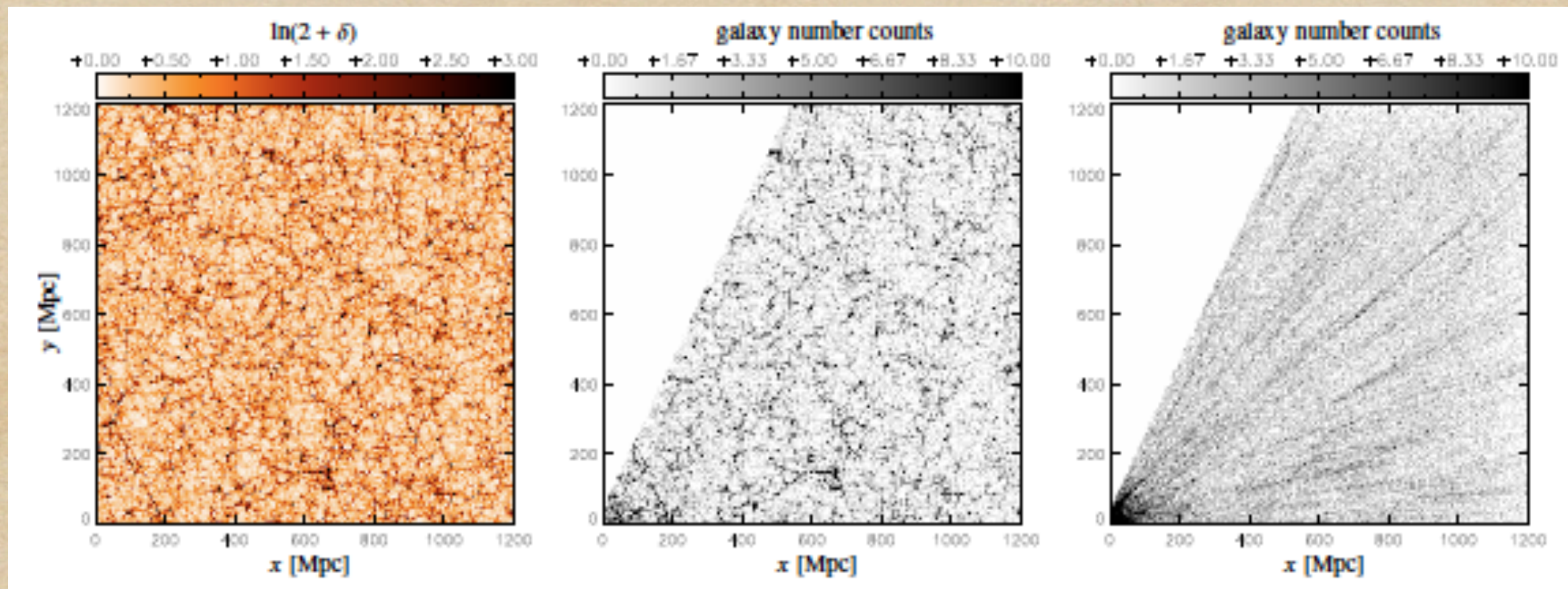


Template fitting

Neural networks

$$\frac{\sigma_z}{1+z} = 0.03$$

Right priors - J. Jasche, B. Wandelt 2012



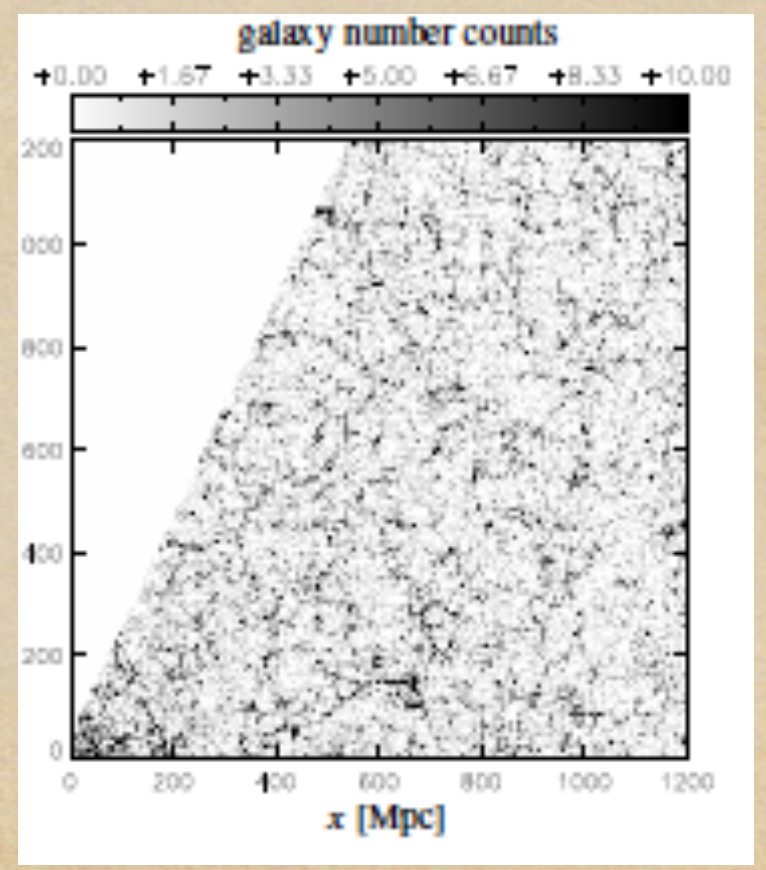
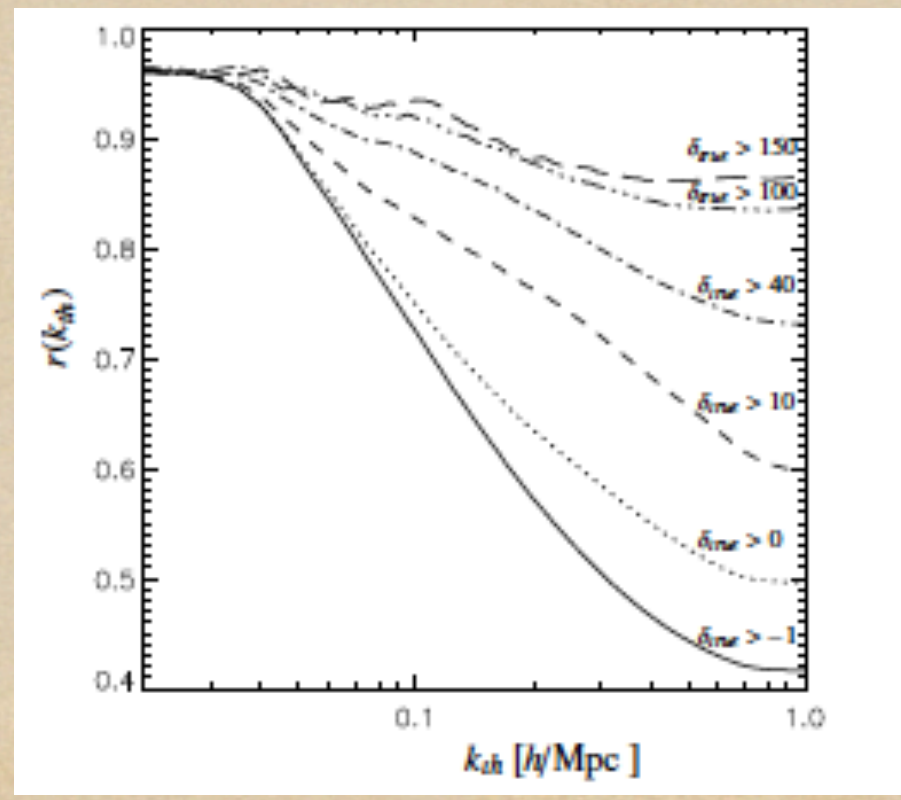
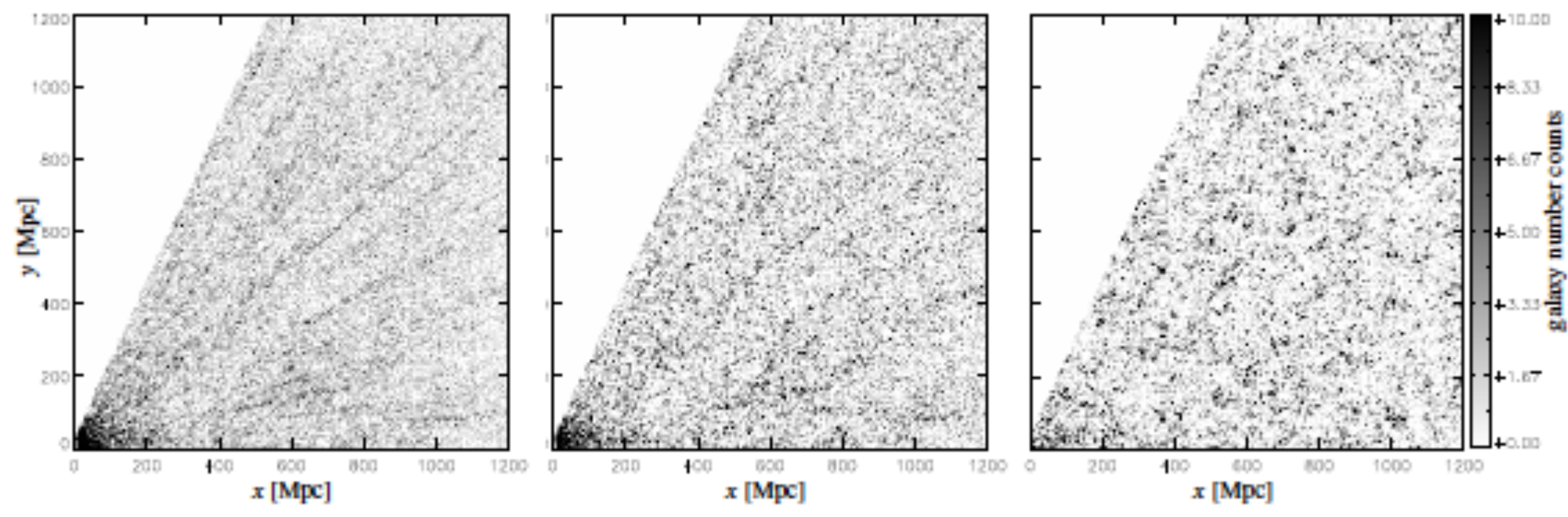
Log-normal Poissonian model

Isotropic covariance matrix (finite range)



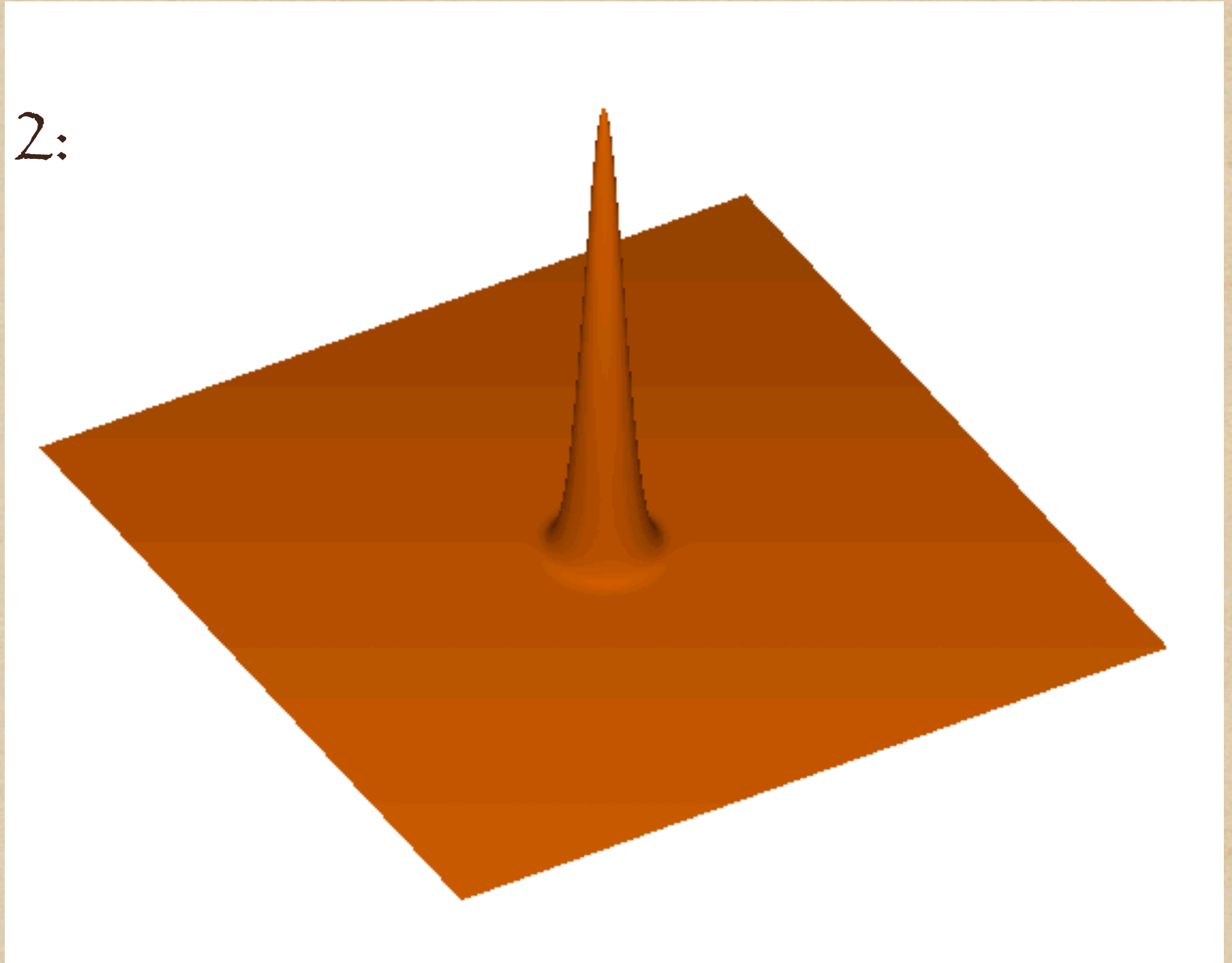
$z \rightarrow \rho$ $D = 10^6$ Hamiltonian MC sampler

$\rho \rightarrow z$ Multiple block Metropolis-Hastings sampler

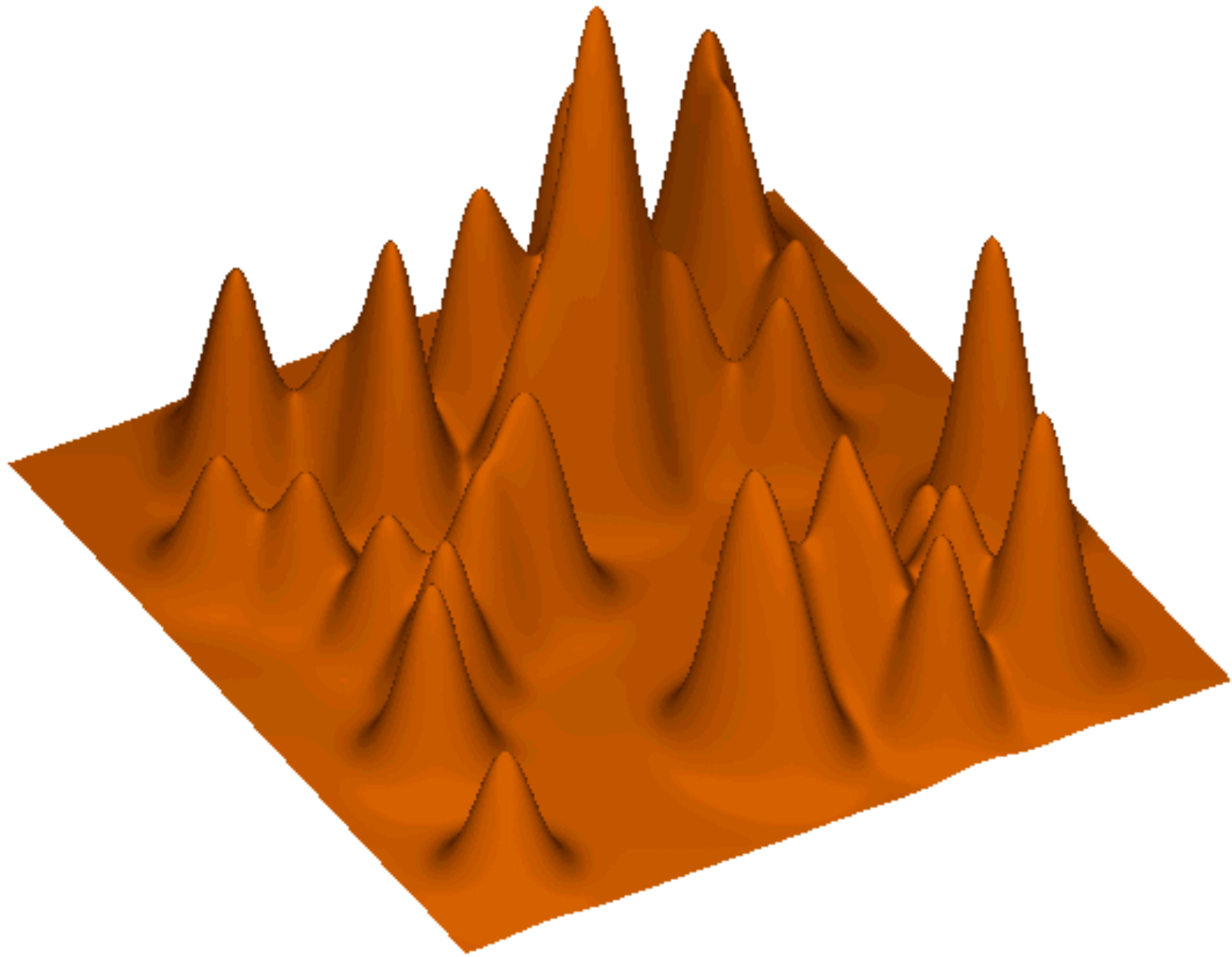


Example 2:

BAO



yardstick to measure the Universe

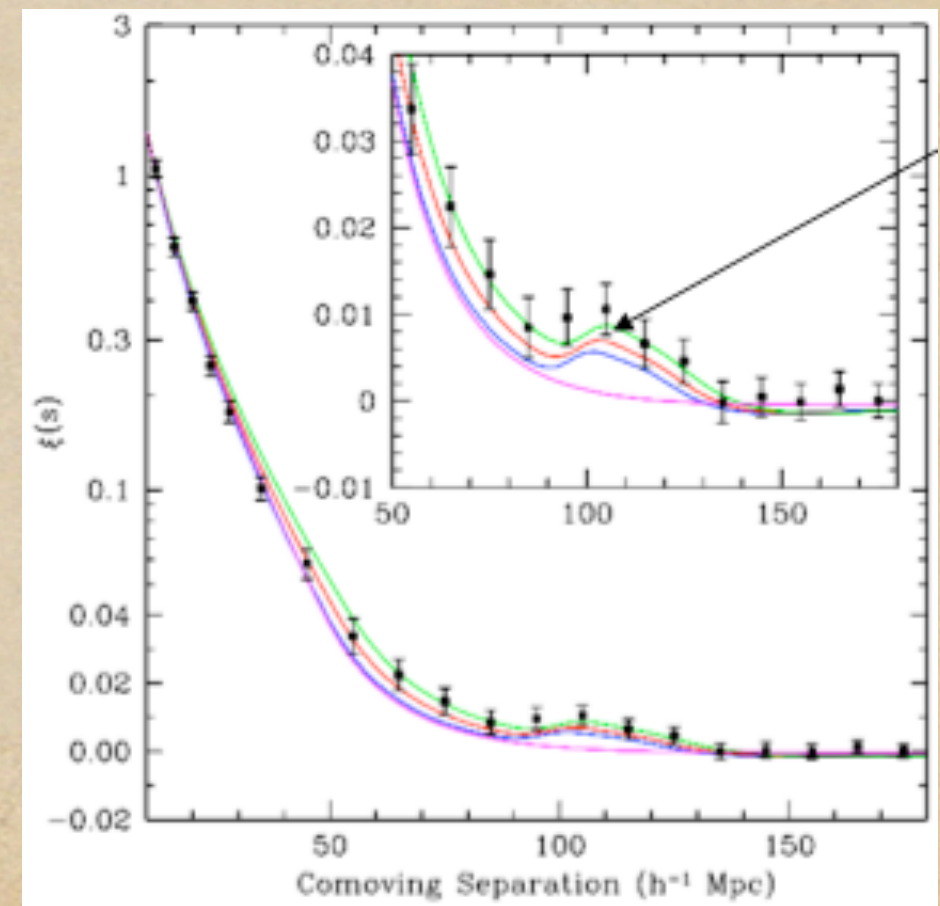
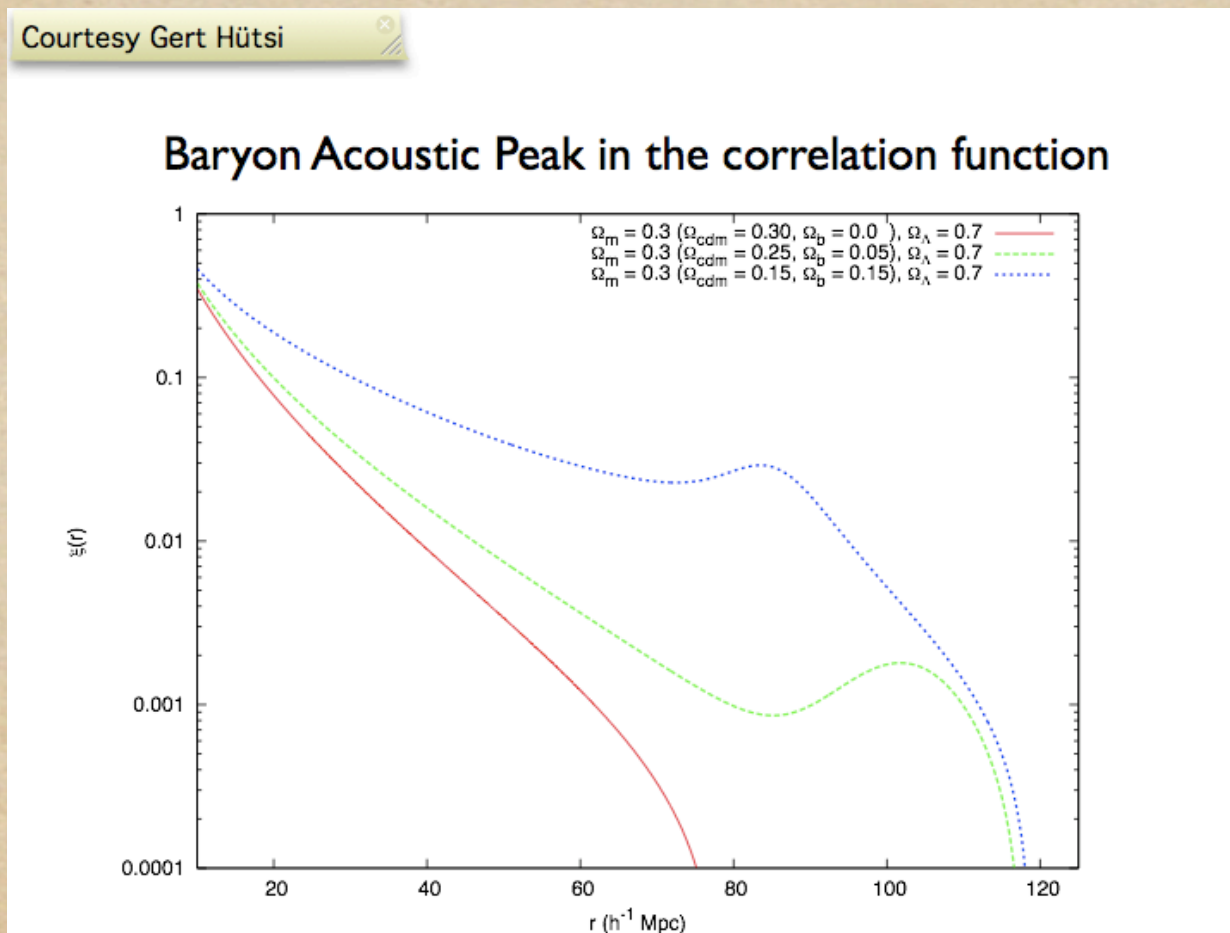


Pair correlation function:

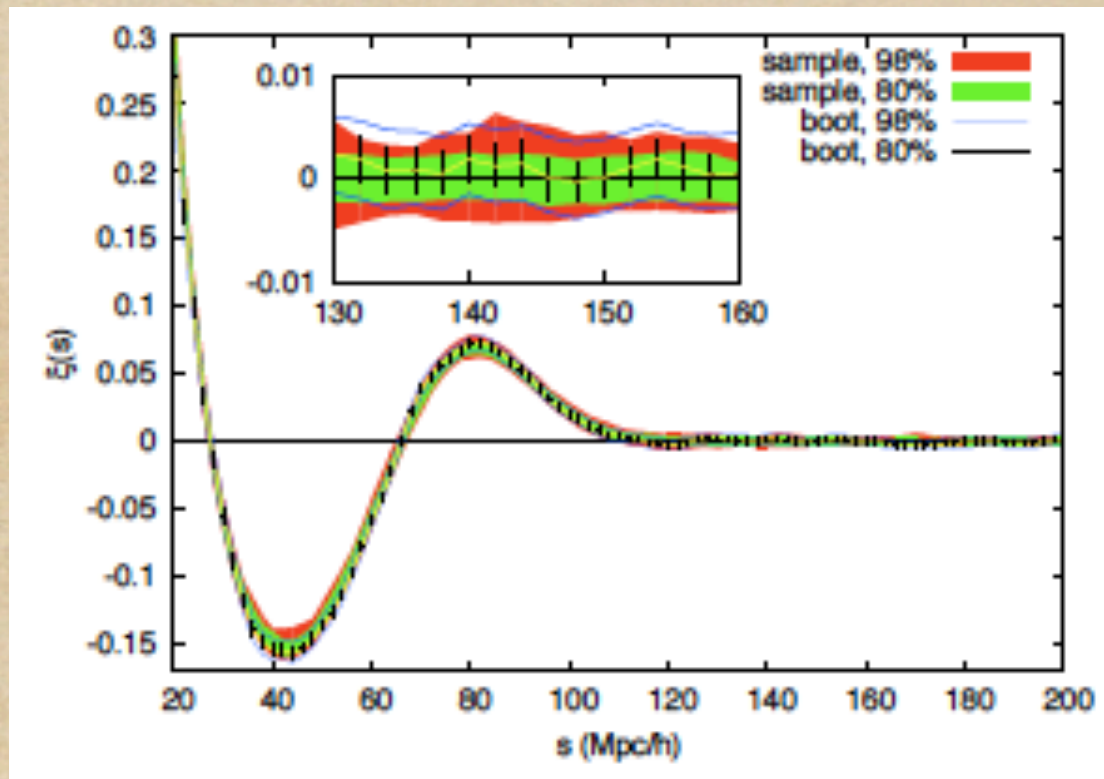
$$dP_{12} = \bar{n}^2 (1 + \xi(\mathbf{r})) dV_1 dV_2$$

Landy-Szalay estimator:

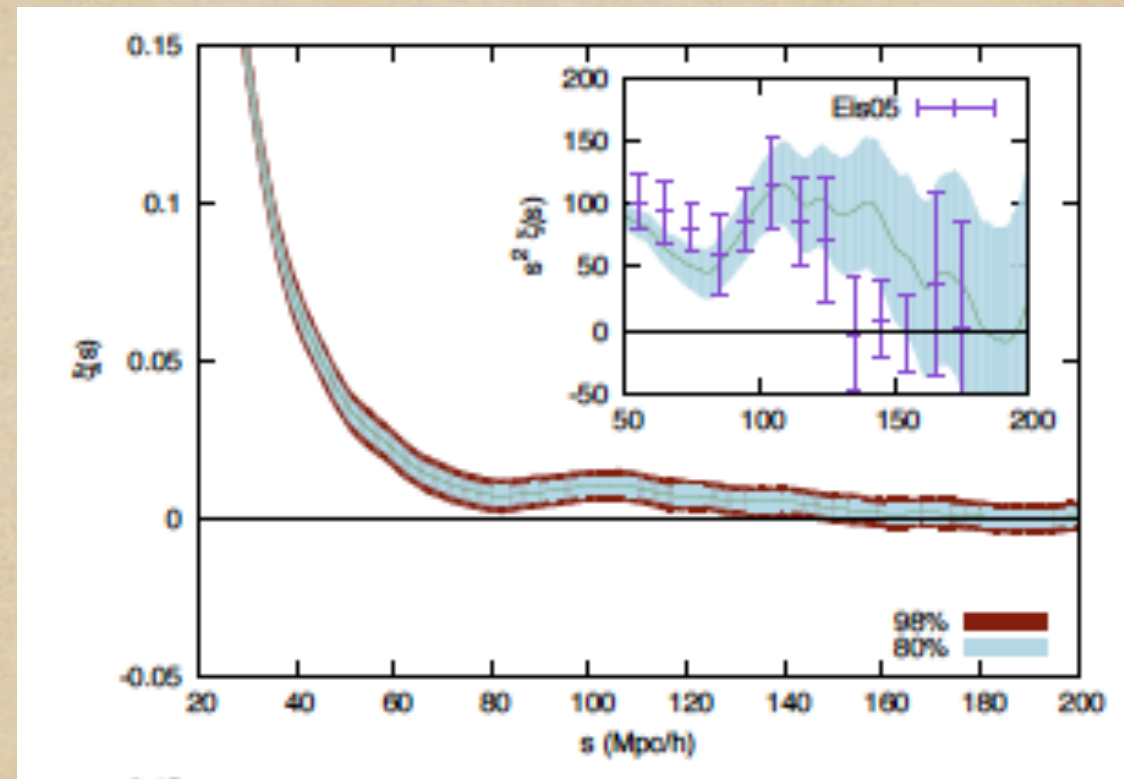
$$\hat{\xi}_{LS}(r) = 1 + \left(\frac{N_{rd}}{N} \right)^2 \frac{DD(r)}{RR(r)} - 2 \frac{N_{rd}}{N} \frac{DR(r)}{RR(r)}$$



Bootstrap confidence limits

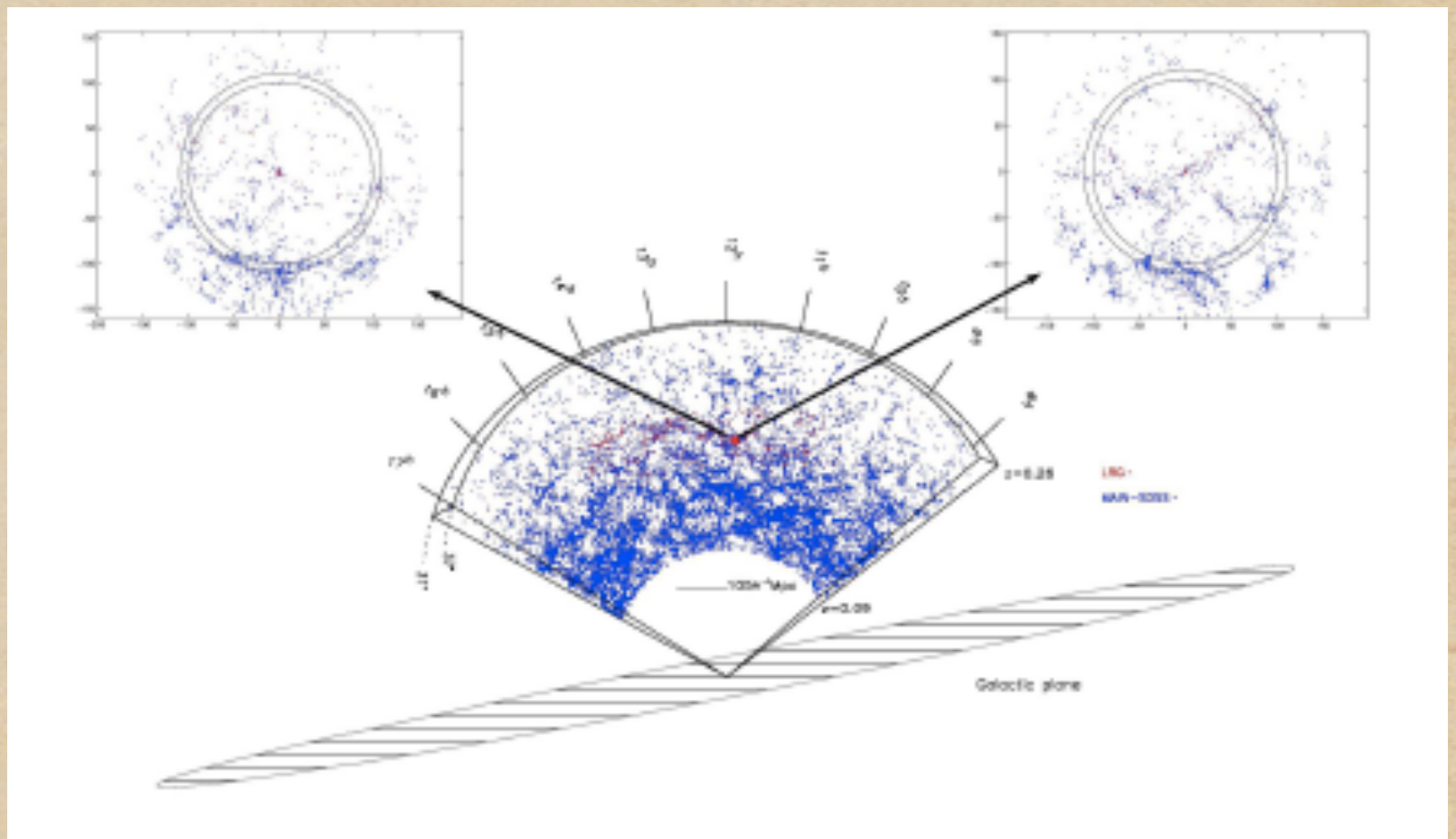
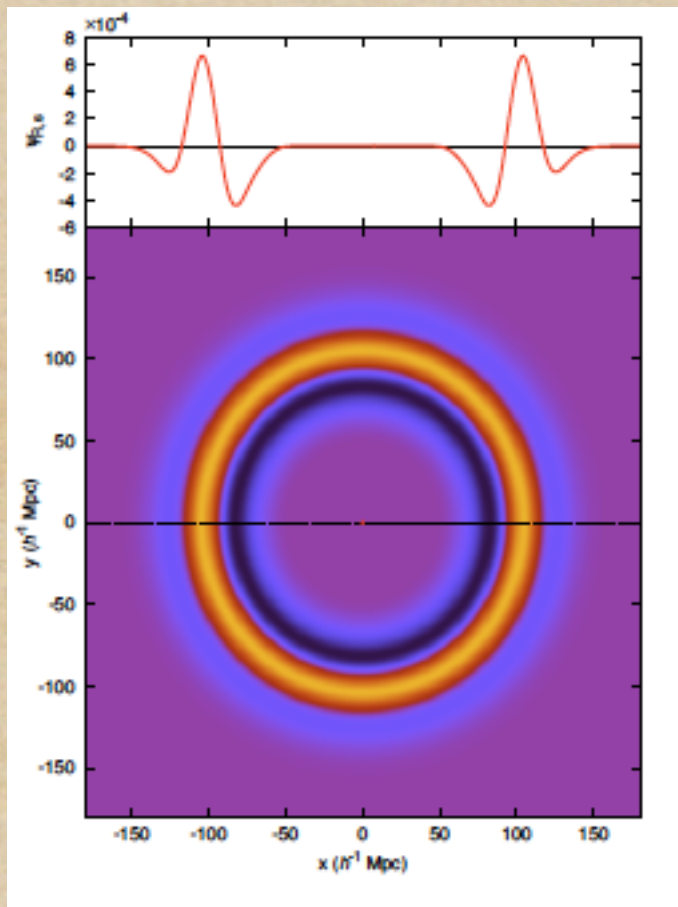


Poisson-Voronoi



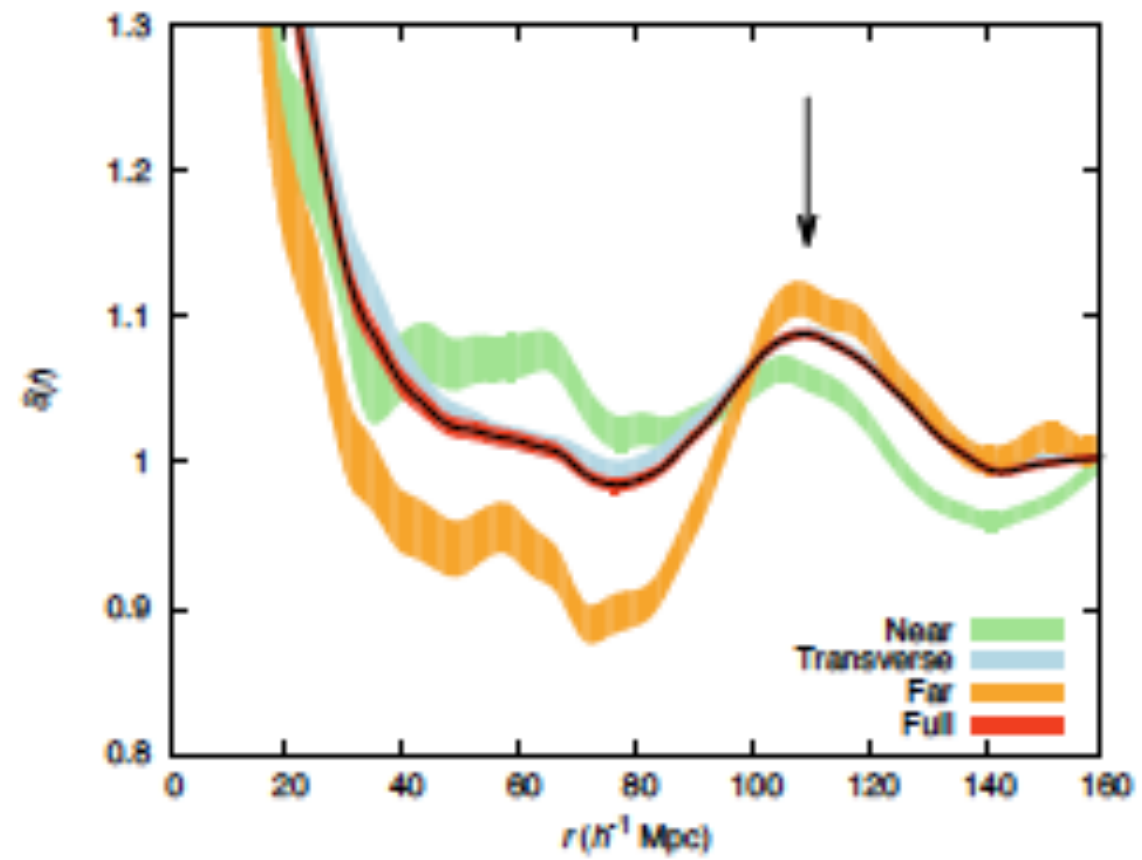
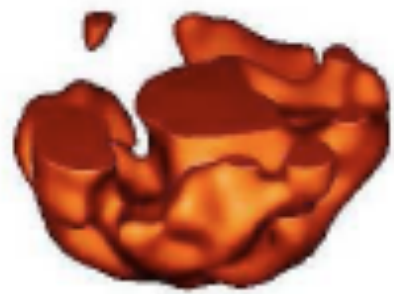
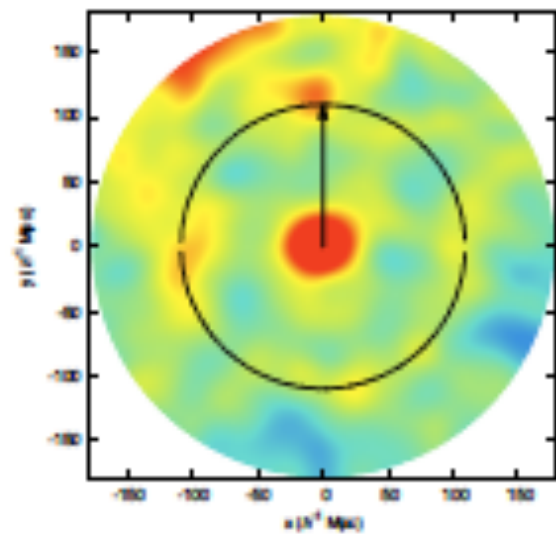
SDSS DR7 LRG's

BAO shells



$$\psi(r|R, s) = \frac{\alpha(R, s)}{4\pi r^2} \left[2B_3 \left(2\frac{r-R}{s} \right) - B_3 \left(\frac{r-R}{s} \right) \right]$$

Stacking



Thank you!