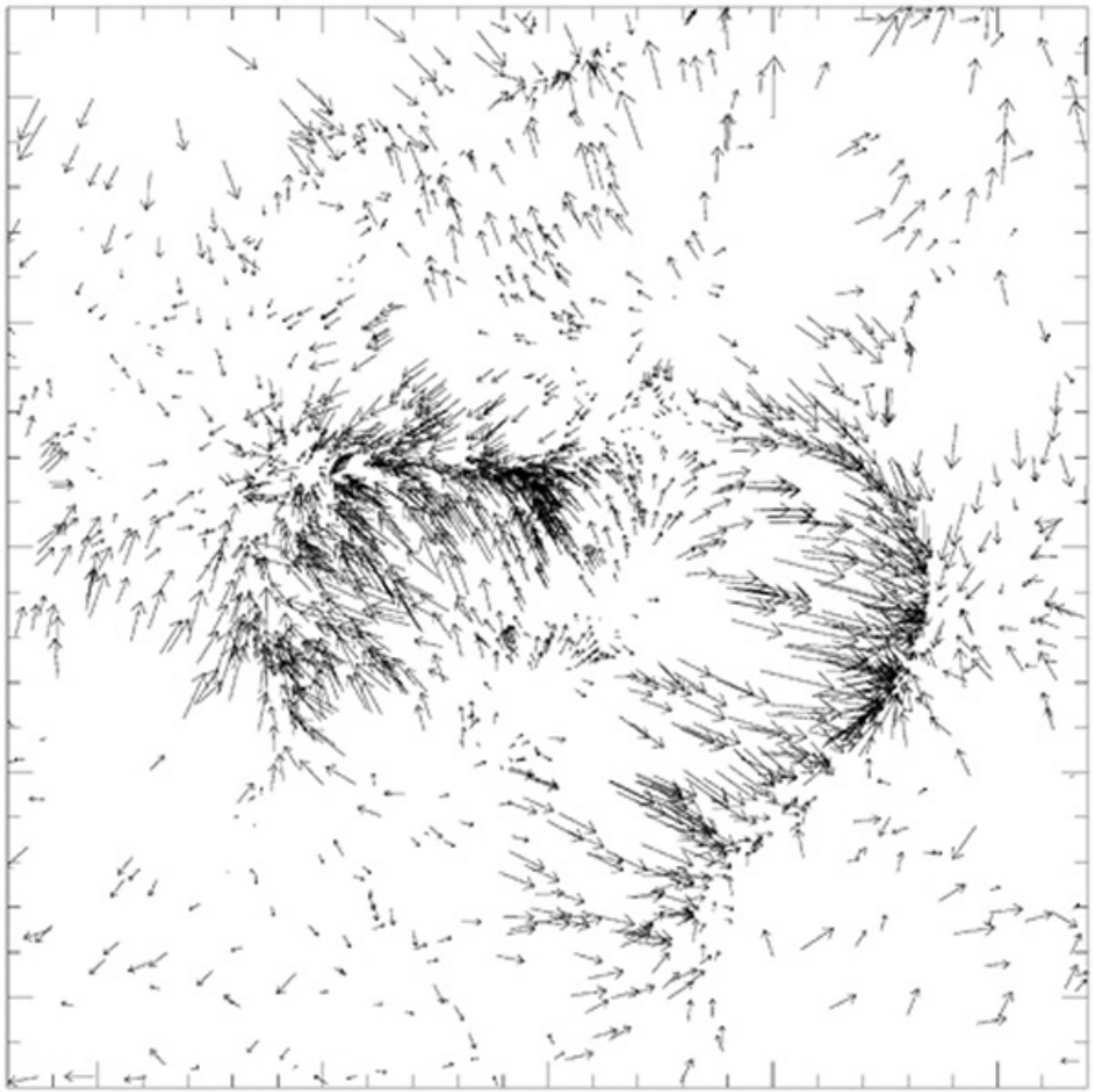
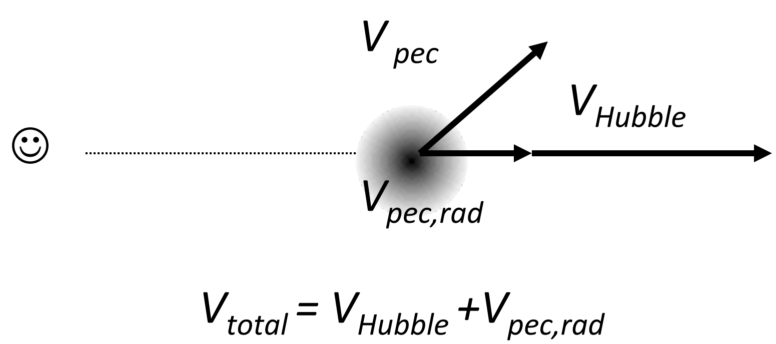
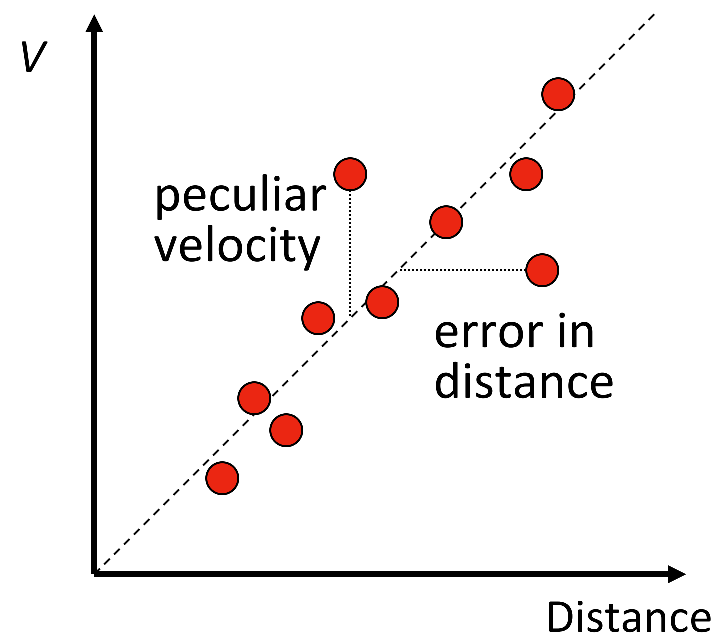
The Large Scale Velocity Field



Peculiar Velocities

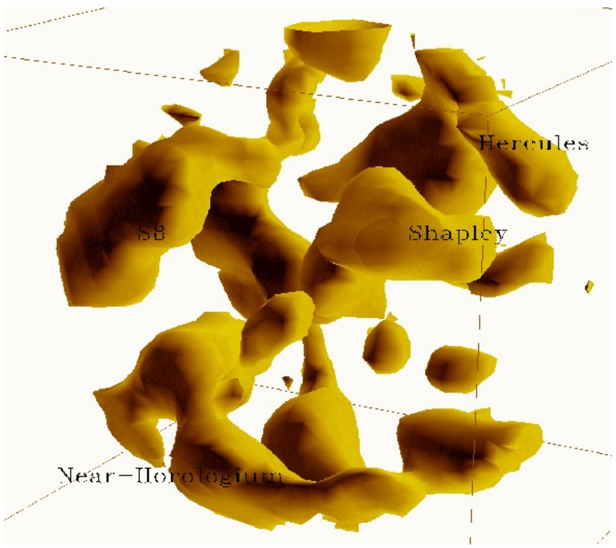
- It means velocities of galaxies in addition to their Hubble flow velocities, i.e., relative to their comoving coordinates restframe
- Note that we can in practice only observe the radial component
- They act as a noise (on the $V = cz$ axis, and in addition to errors of distances) in the Hubble diagram - and could thus bias the measurements of the H_0 (which is why we want "far field" measurements)

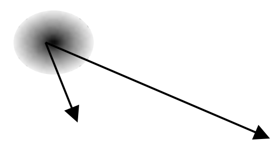




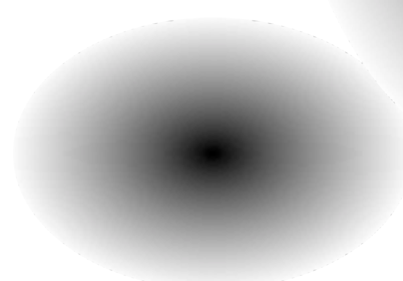
Large-Scale Density Field Inevitably Generates a Peculiar Velocity Field

The PSCz survey
local 3-D density field





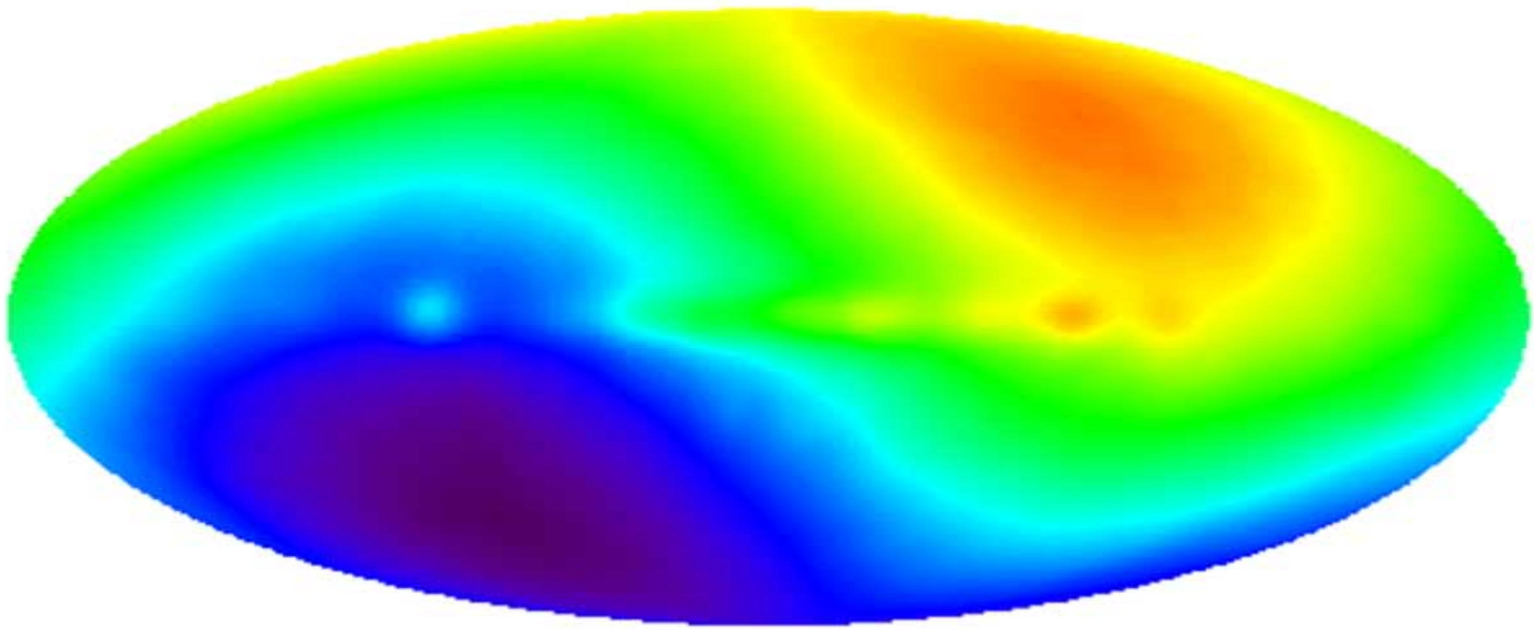
A galaxy is accelerated towards the nearby large mass concentrations



Integrated over the Hubble time, this results in a peculiar velocity

The pattern of peculiar velocities should thus reflect the underlying mass density field

CMBR Dipole:
The One Peculiar Velocity We Know Very Well



We are moving wrt. to the CMB at ~ 620 km/s towards $b=27°$, $l=268°$

This gives us an idea of the probable magnitude of peculiar velocities in the local universe. Note that at the distance to Virgo (LSC), this corresponds to a ~ 50% error in Hubble velocity, and a ~ 10% error at the distance to Coma cluster.

How to Measure Peculiar Velocities?

1. Using distances and residuals from the Hubble flow:

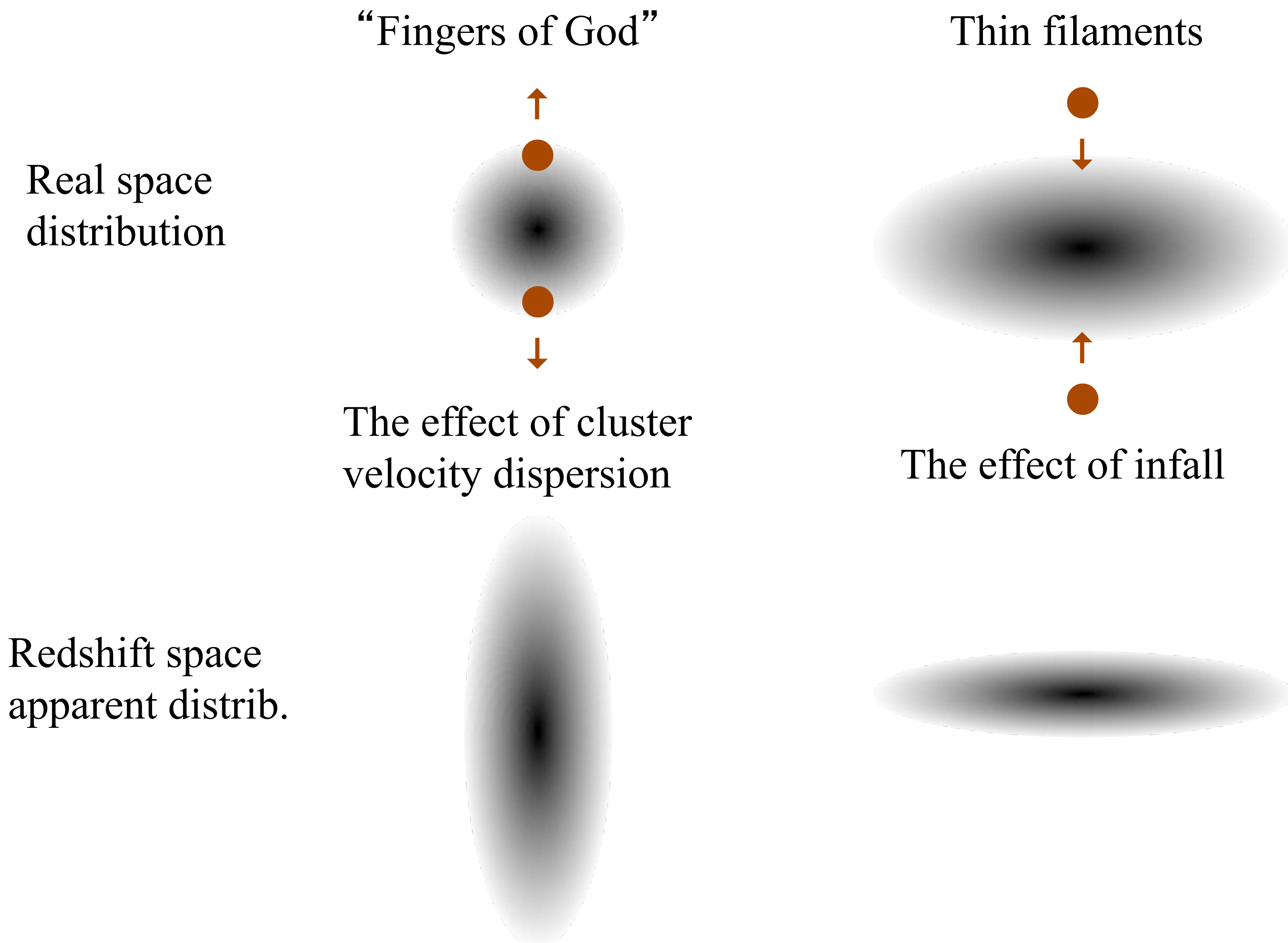
$$V_{total} = V_{Hubble} + V_{pec} = H_0 D + V_{pec}$$

- So, if you know relative distances, e.g., from Tully-Fisher, or D_n-σ relation, SBF, SNe, …you could derive peculiar velocities
- A problem: distances are seldom known to better than ~10% (or even 20%), multiply that by V_{Hubble} to get the error of V_{pec}
- Often done for clusters, to average out the errors
- But there could be systematic errors - distance indicators may vary in different environments

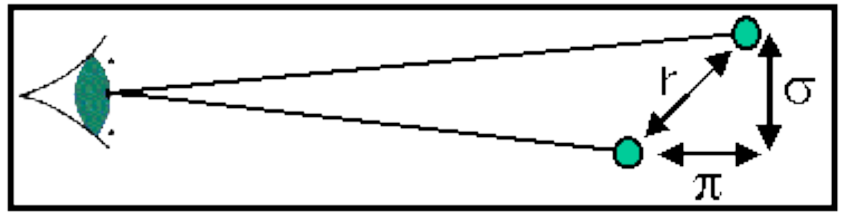
2. Statistically from a redshift survey

- Model-dependent

Redshift Space vs. Real Space



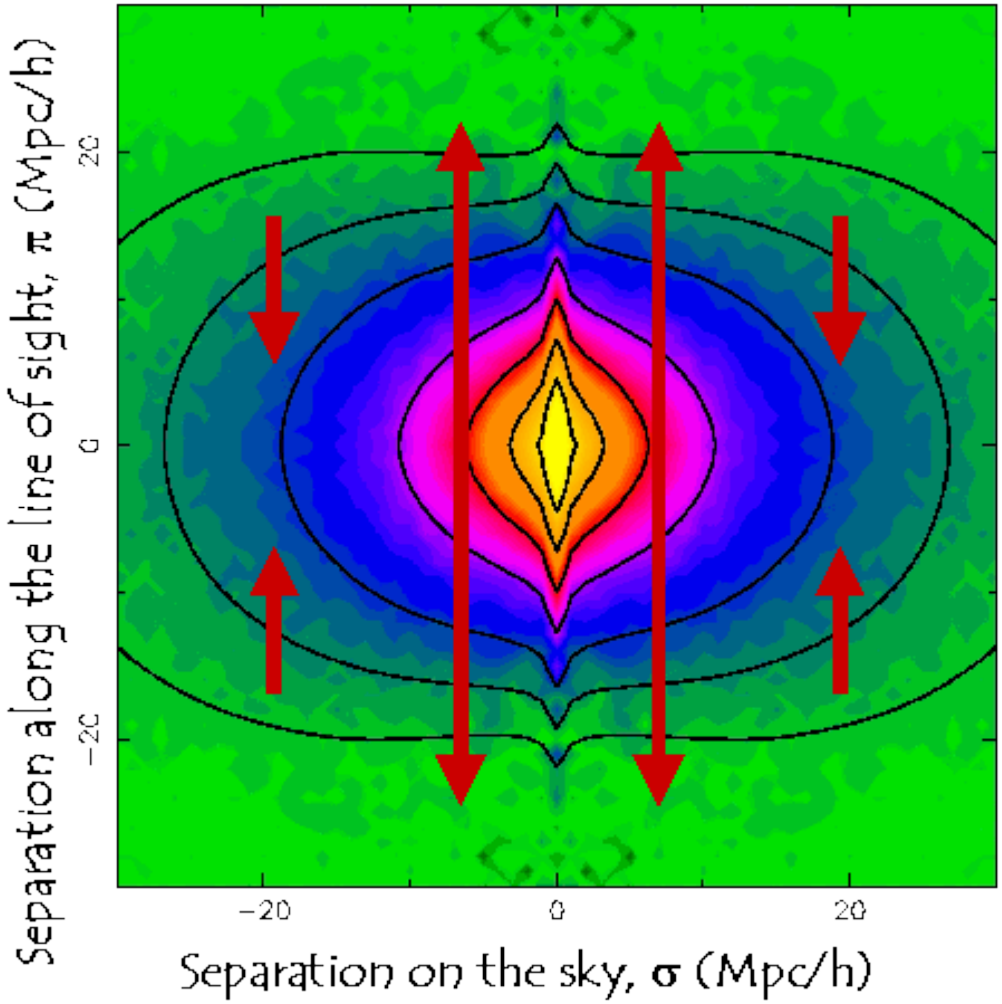
Redshift-Space Correlation Function



Hawkins et al. (2002), astro-ph/0212375

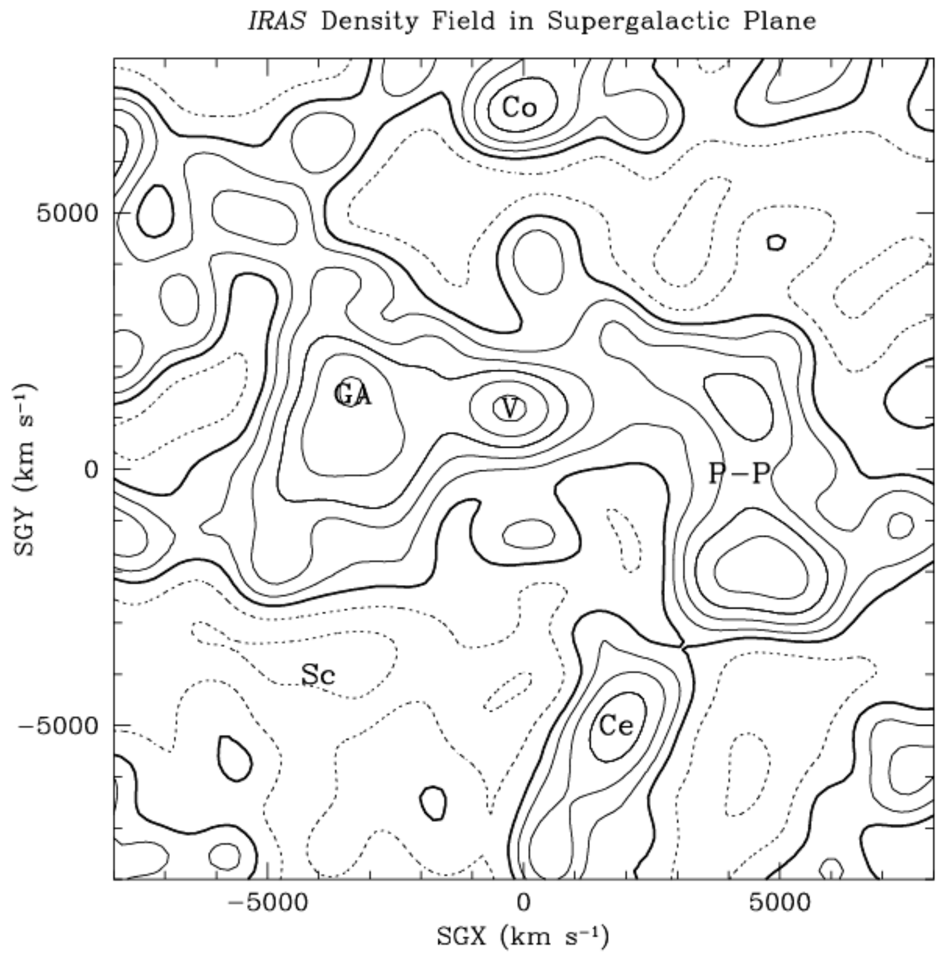
2dFGRS: β = 0.47 ± 0.09

- Small $\sigma \Rightarrow$ non-linear 'Finger-of-God' effect
- Large $\sigma \Rightarrow$ flattening due to coherent infall
- Fit to r = 8–30 h^{-1} Mpc; (nb: ‹z›=0.15, ‹L›=1.4L*)
- Distortion parameter $\beta = \Omega^{0.6}/b = 0.47 \pm 0.09$
- Pair-wise vel. dispersion $\sigma_p = 495 \pm 52$ km/s
- If $b \approx 1 \Rightarrow \Omega \approx 0.21$
- If $\Omega \approx 0.3 \Rightarrow b \approx 1.2$

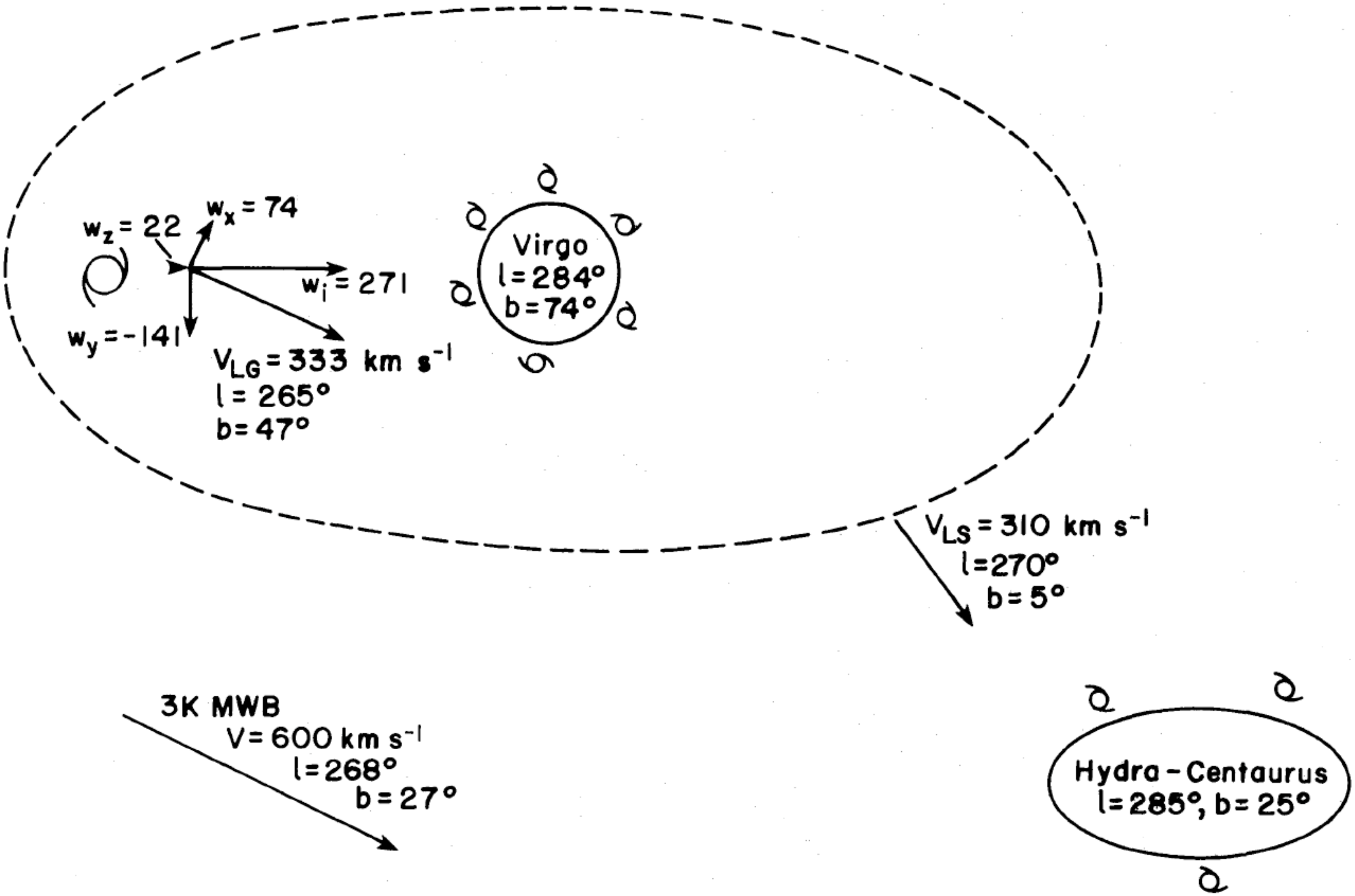


Measuring Peculiar Velocity Field Using a Redshift Survey

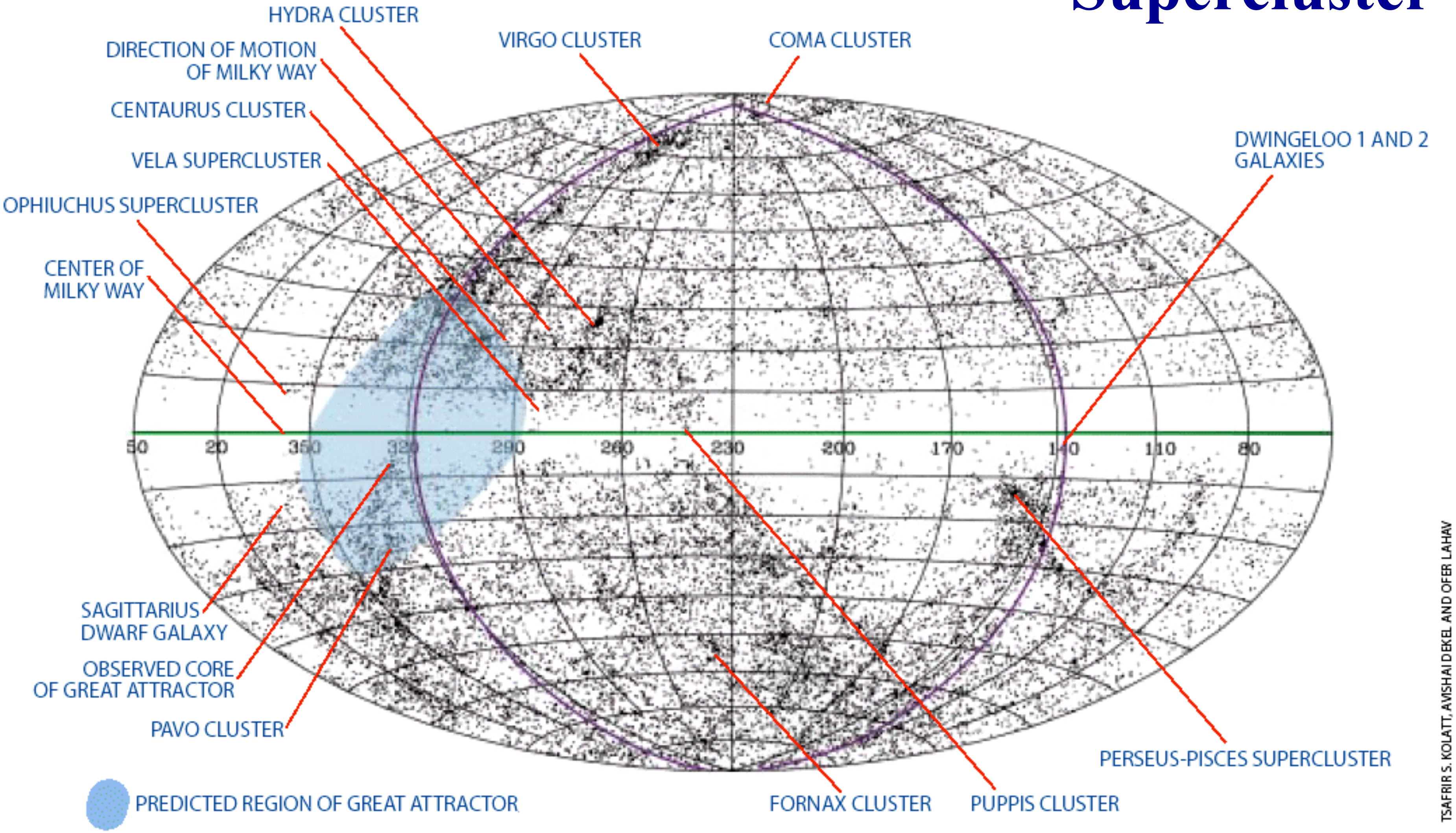
- Assume that galaxies are where their redshifts imply; this gives you a density field
- You need a model on how the light traces the mass
- Evaluate the accelerations for all galaxies, and their esimated peculiar velocities
- Update the positions according to new Hubble velocities
- Iterate until the convergence
- You get a consistent density and velocity field



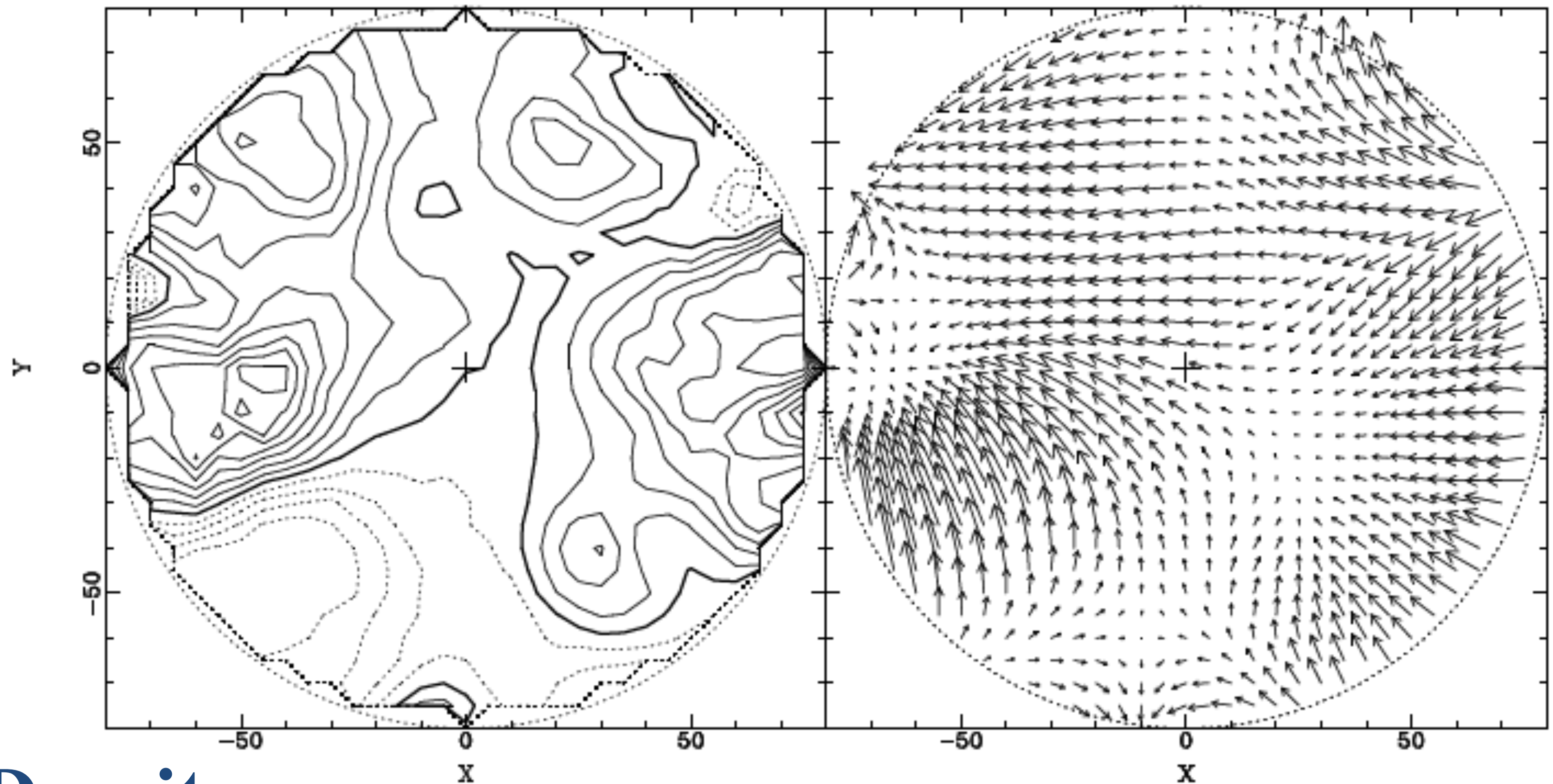
Virgo Infall, and the Motion Towards the Hydra-Centaurus Supercluster



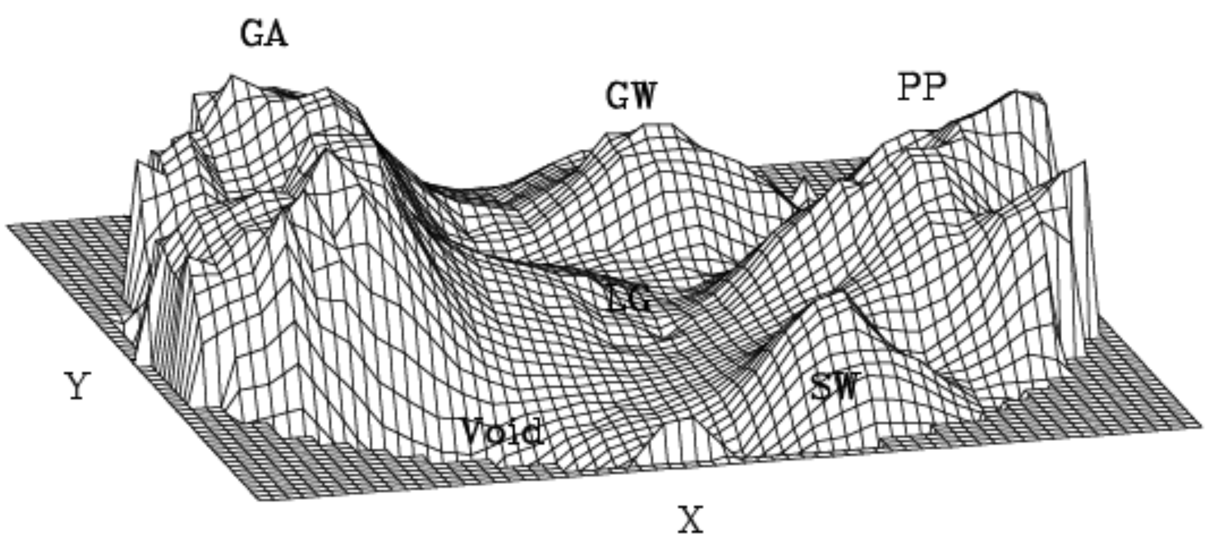
The "Great Attractor" aka the Hydra-Centaurus Supercluster



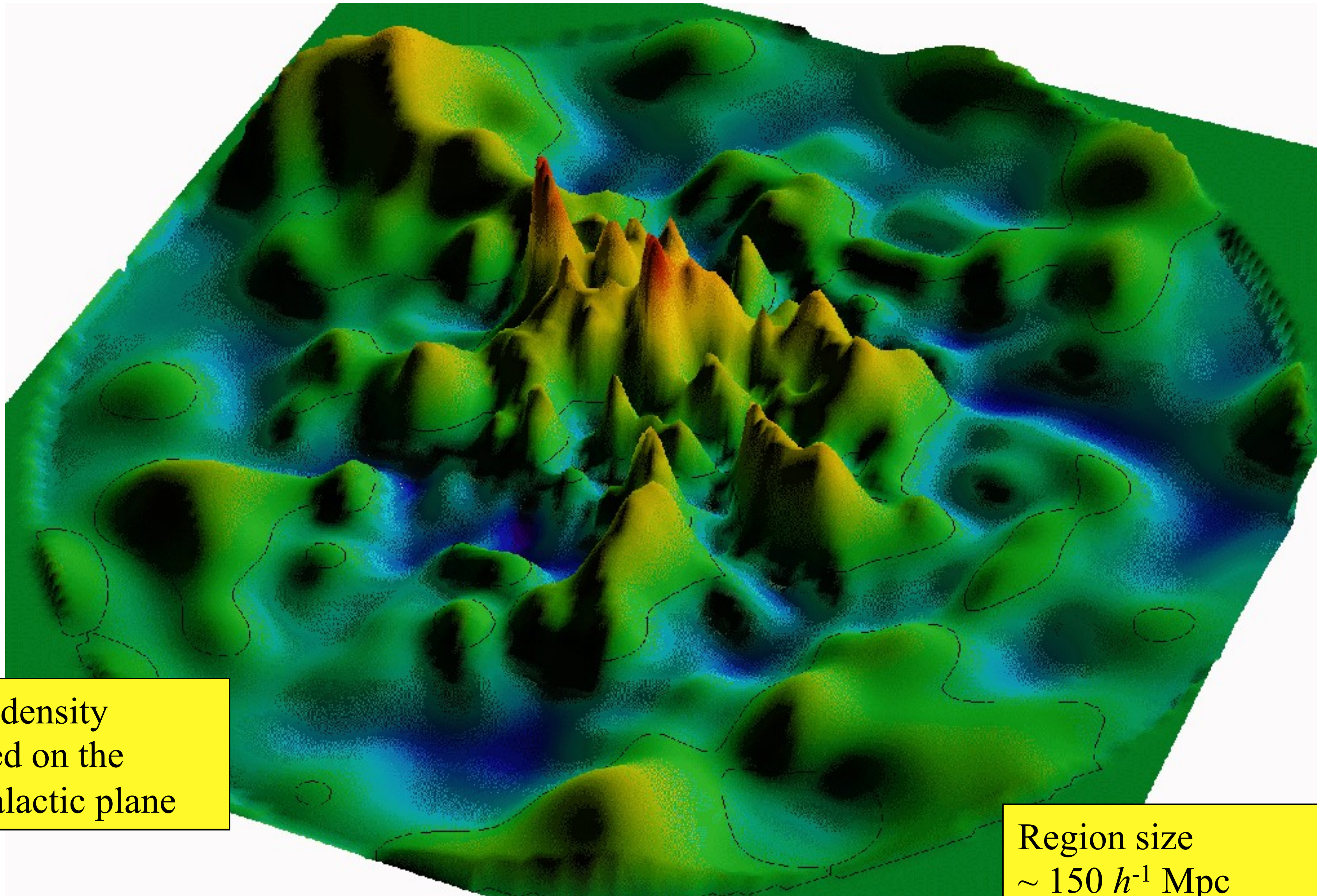
30,000 GALAXIES, culled from three standard astronomical catalogues, are shown as dots on this map. The galaxies appear all over the sky except in the so-called zone of avoidance, which corresponds to the plane of our Milky Way galaxy (*green horizontal center line*). Outside the zone, the galaxies tend to clump near a line that traces out the Supergalactic Plane (*purple line*).



Local Density and Velocity Fields From Peculiar Velocities of Galaxies



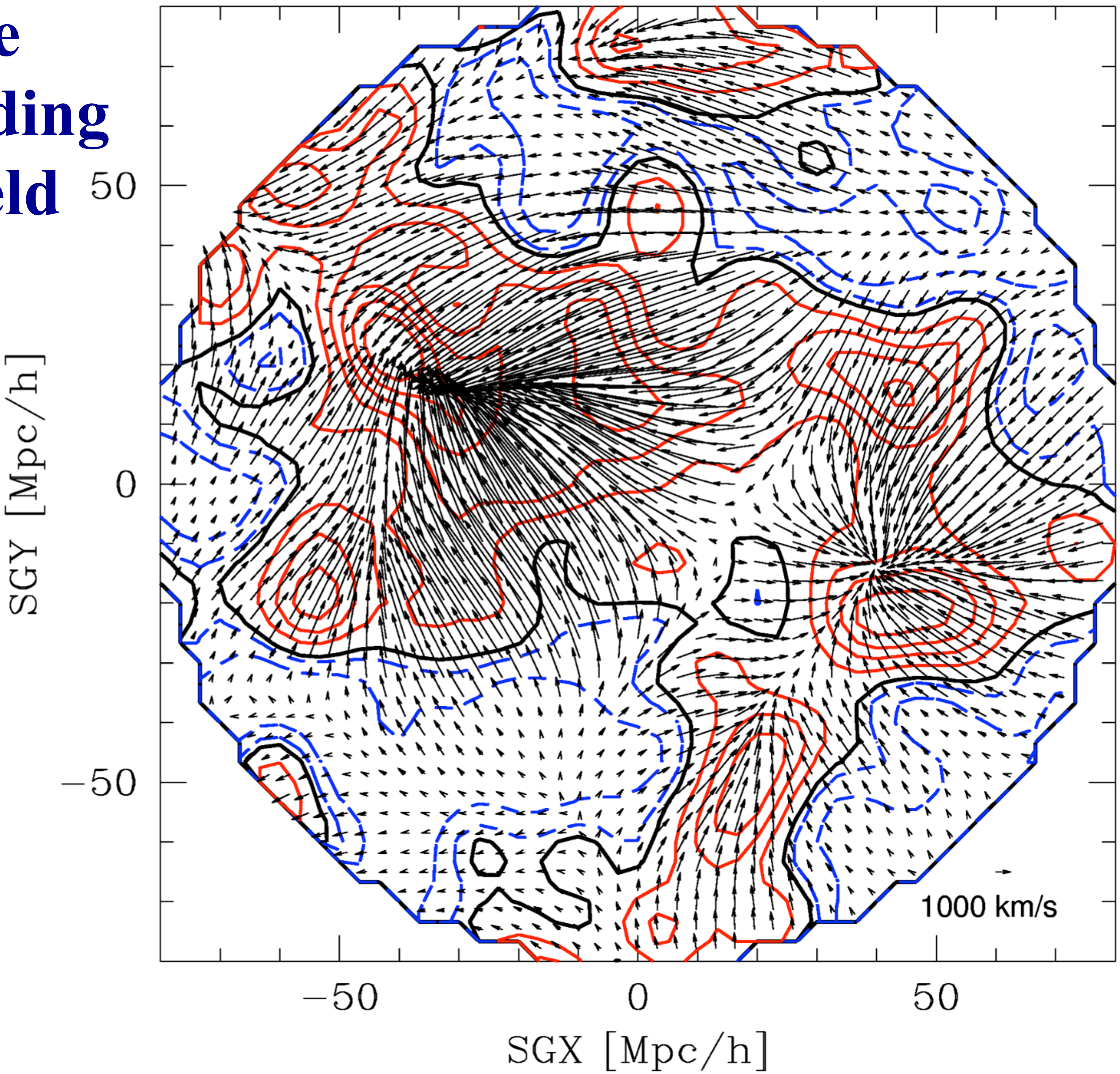
Density Field From the PSCz Redshift Survey



Galaxy density projected on the Supergalactic plane

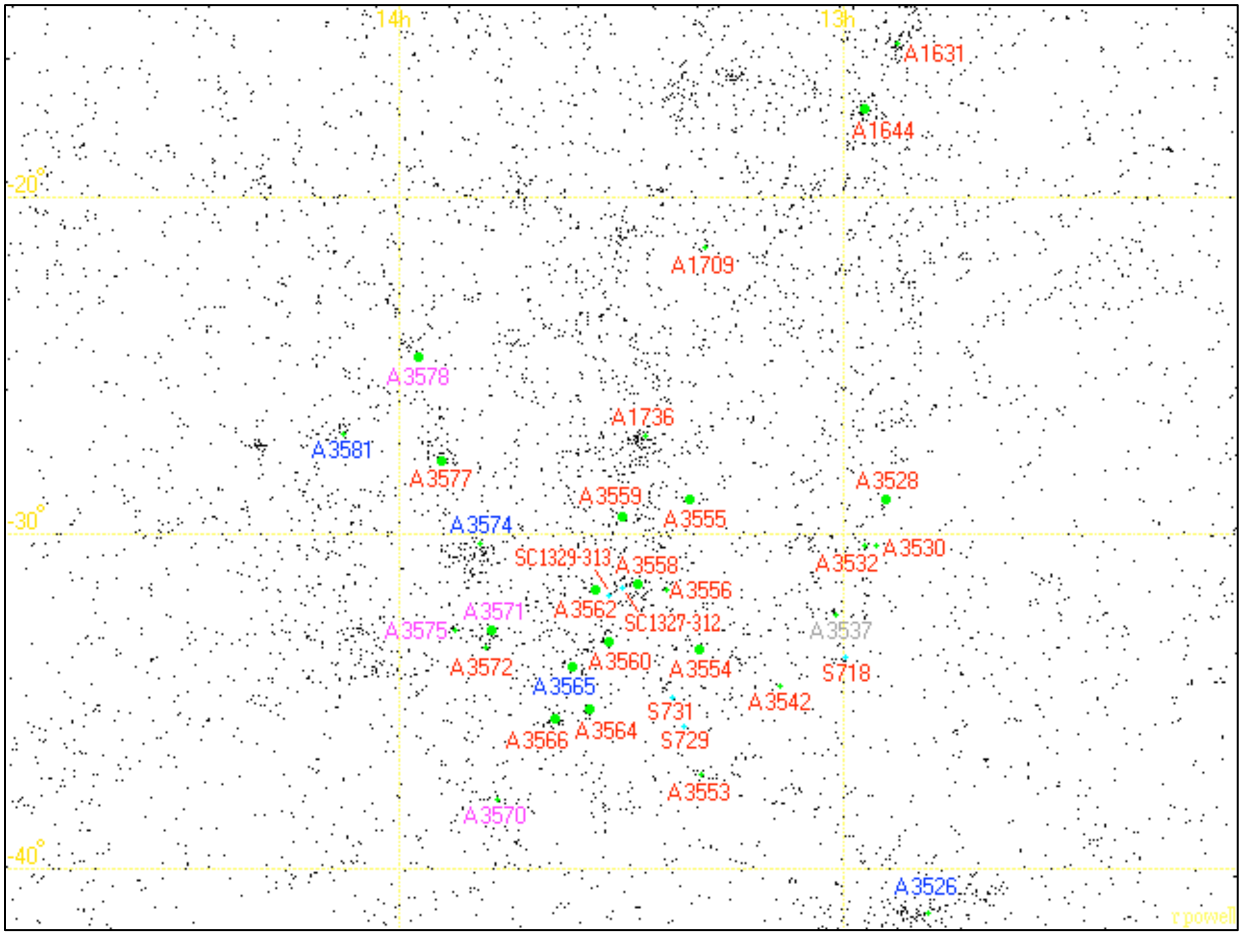
Region size ~ 150 h^{-1} Mpc

PSCz: The corresponding velocity field



The Flow Continues?

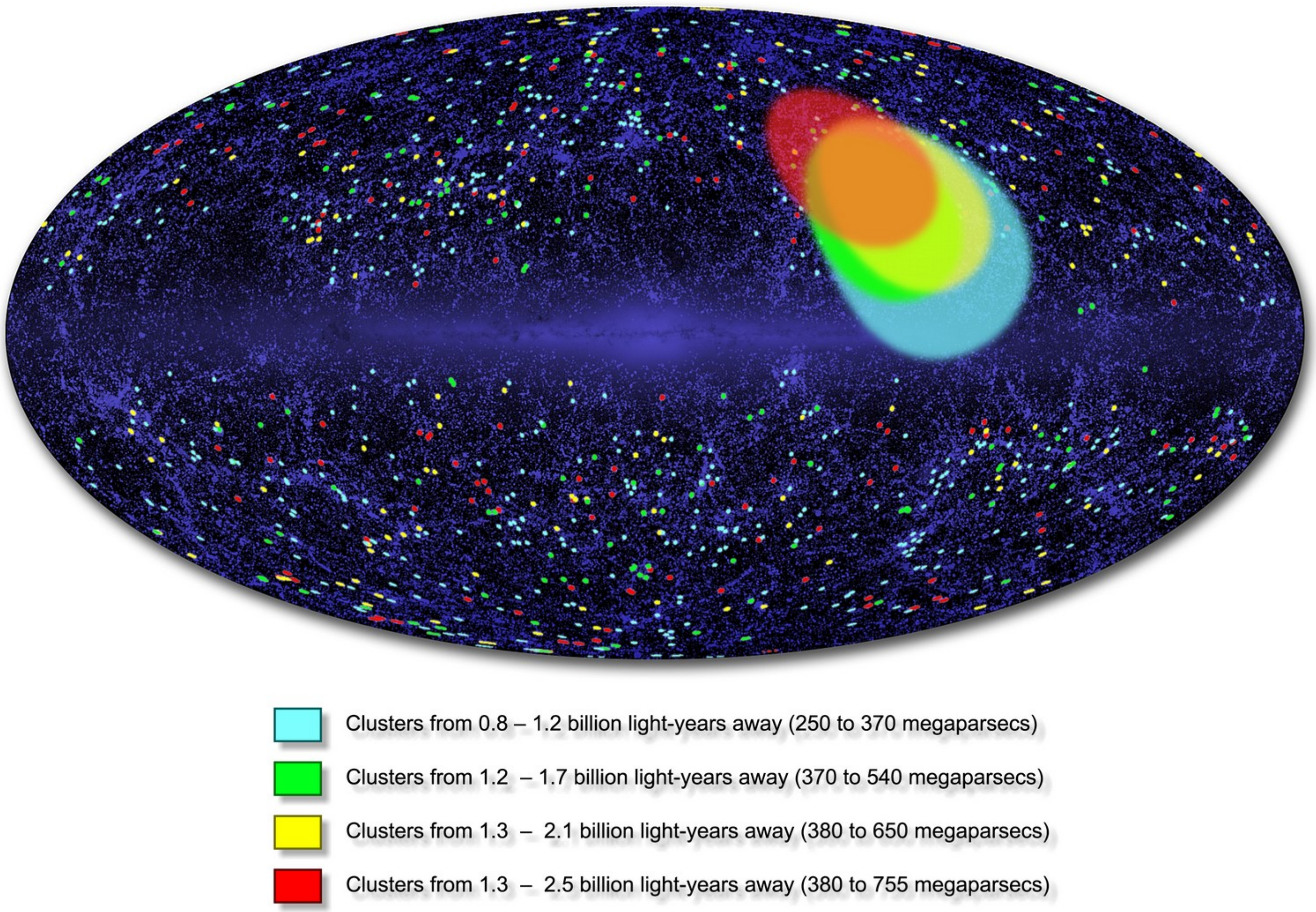
The Shapley Concentration of clusters at ~ 200 Mpc, beyond the Hydra-Centaurus may be responsible for at least some of the large-scale bulk flow



How Far Does It Go? "The Dark Flow"

Kaslinsky et al. measured peculiar velocities of clusters, and find that the flow extends to even larger scales, approaching a Gpc – and maybe beyond

"Dark flow" galaxy clusters and flow direction by distance



Peculiar Velocities: Summary

- Measurements of peculiar velocities are very, very tricky
  - Use (relative) distances to galaxies + Hubble flow, to infer the peculiar velocities of individual galaxies. Systematic errors?
  - Use a redshift survey + numerical modeling to infer the mass density distribution and the consistent peculiar velocity field
- Several general results:
  - We are falling towards Virgo with ~ 300 km/s, and will get there in about 10 - 15 Gyr
  - Our peculiar velocity dipole relative to CMB originates from within ~ 50 Mpc
  - The LSC is falling towards the Hydra-Centaurus Supercluster, with a speed of up to 500 km/s
  - The whole local ~ 100 Mpc volume may be falling towards a larger, more distant Shappley Concentration (of clusters)
- The mass and the light seem to be distributed in the same way on large scales (here and now)

Next:
Bias and the Evolution of Clustering