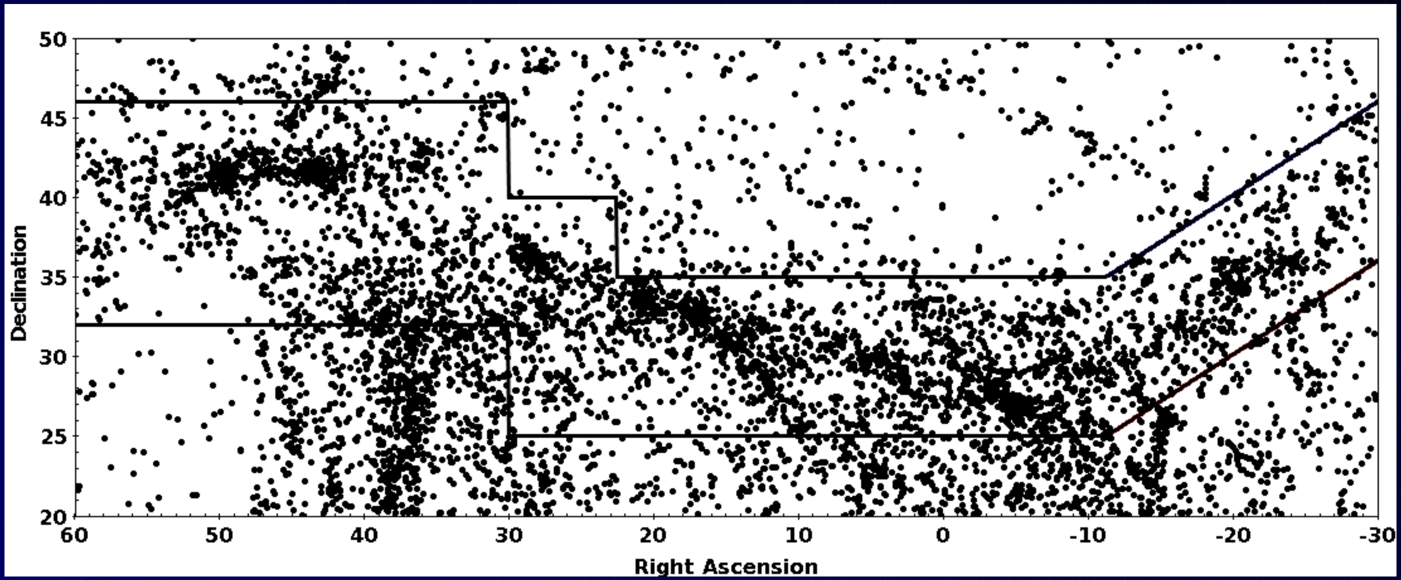
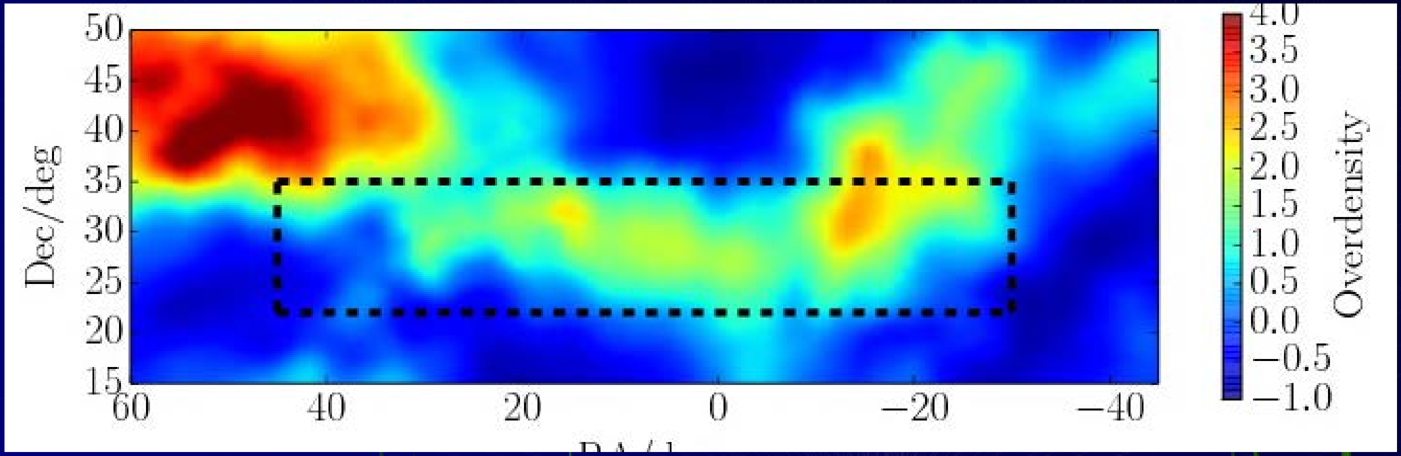
The Arecibo Pisces-Perseus Supercluster Survey



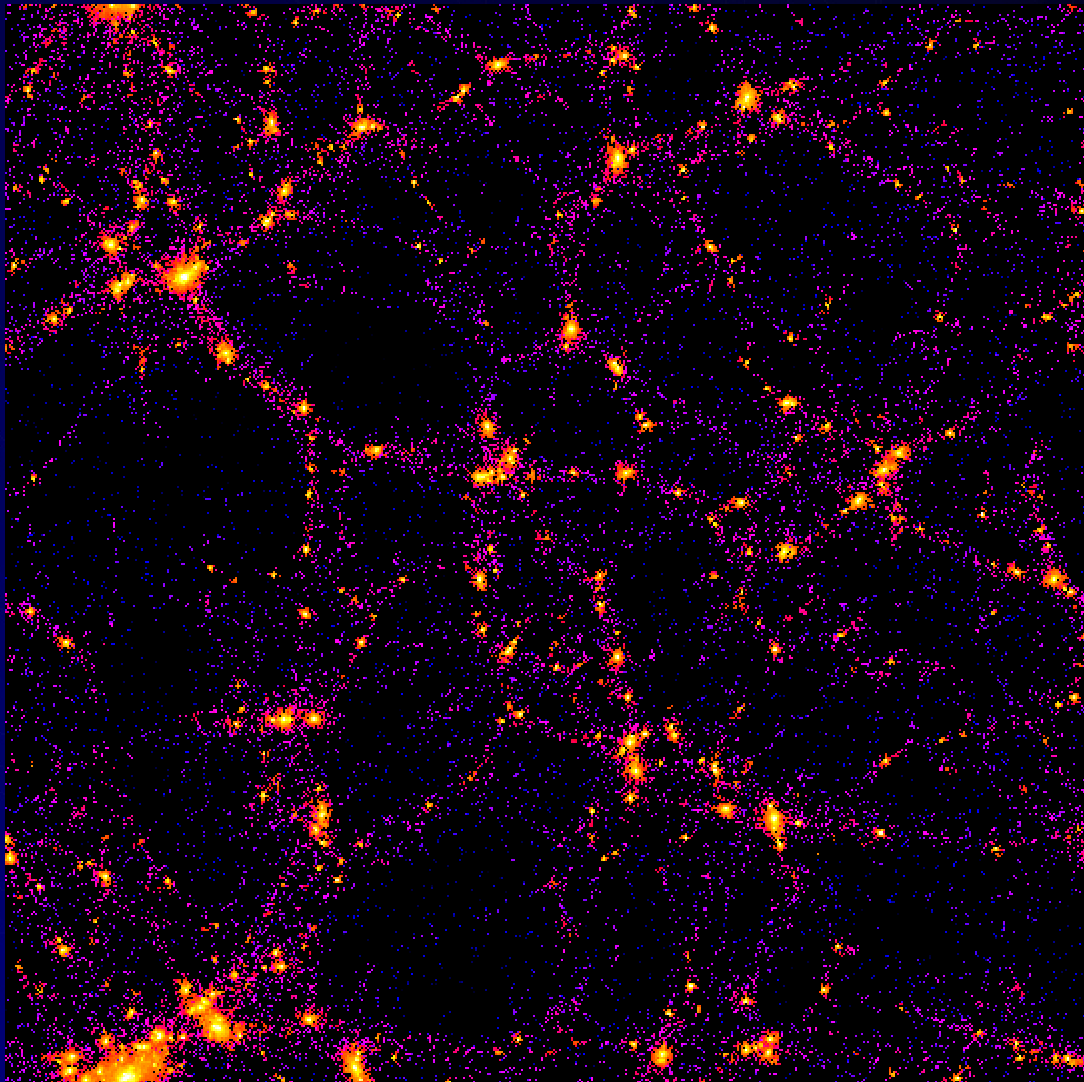


UAT 17.06

Martha Haynes

Cornell University

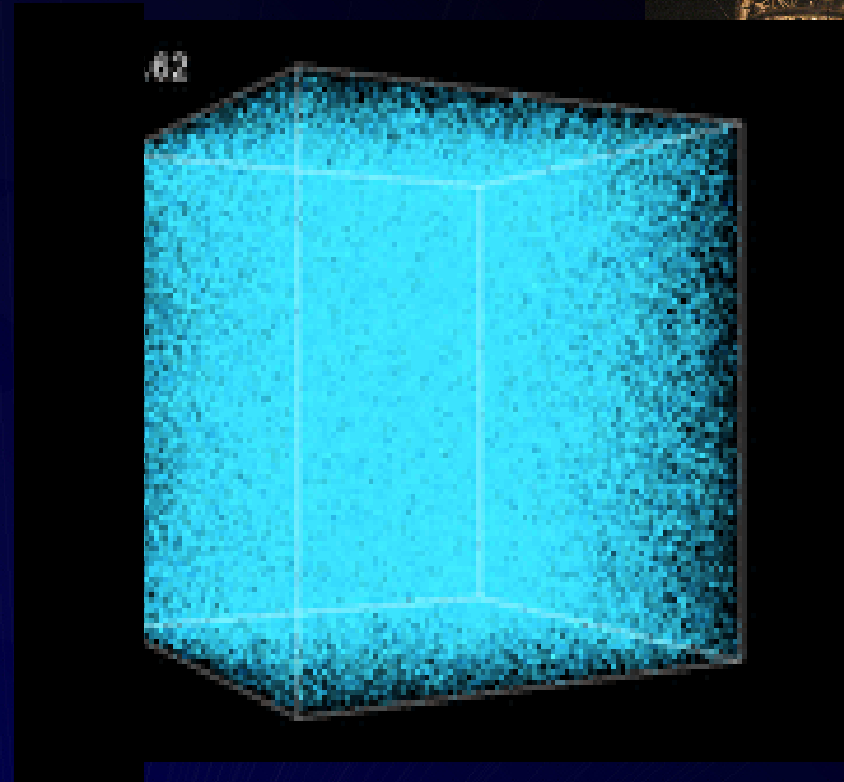
Large scale structure in the Universe

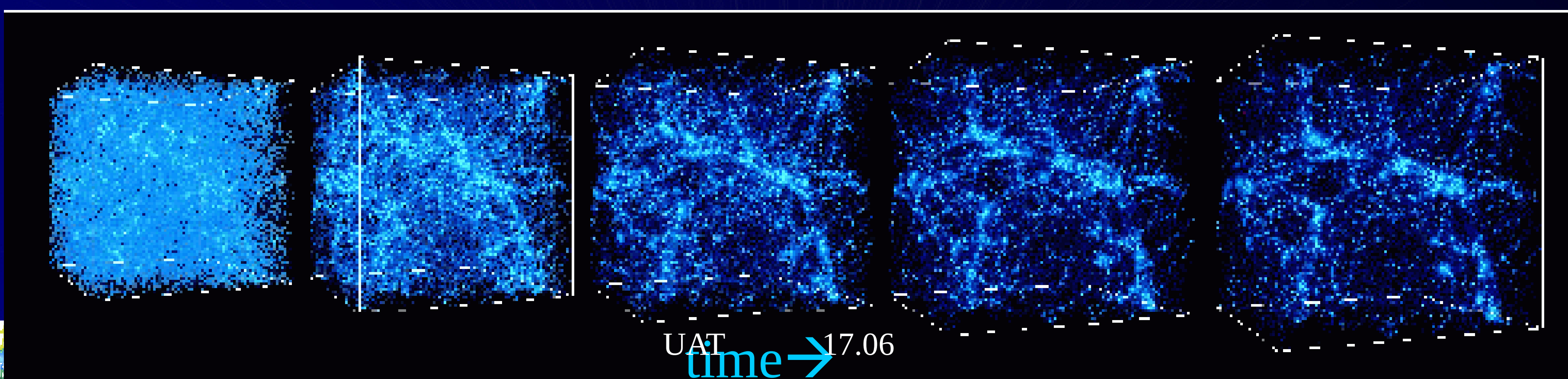


- Galaxies cluster into groups, clusters and superclusters
- Galaxies avoid voids.

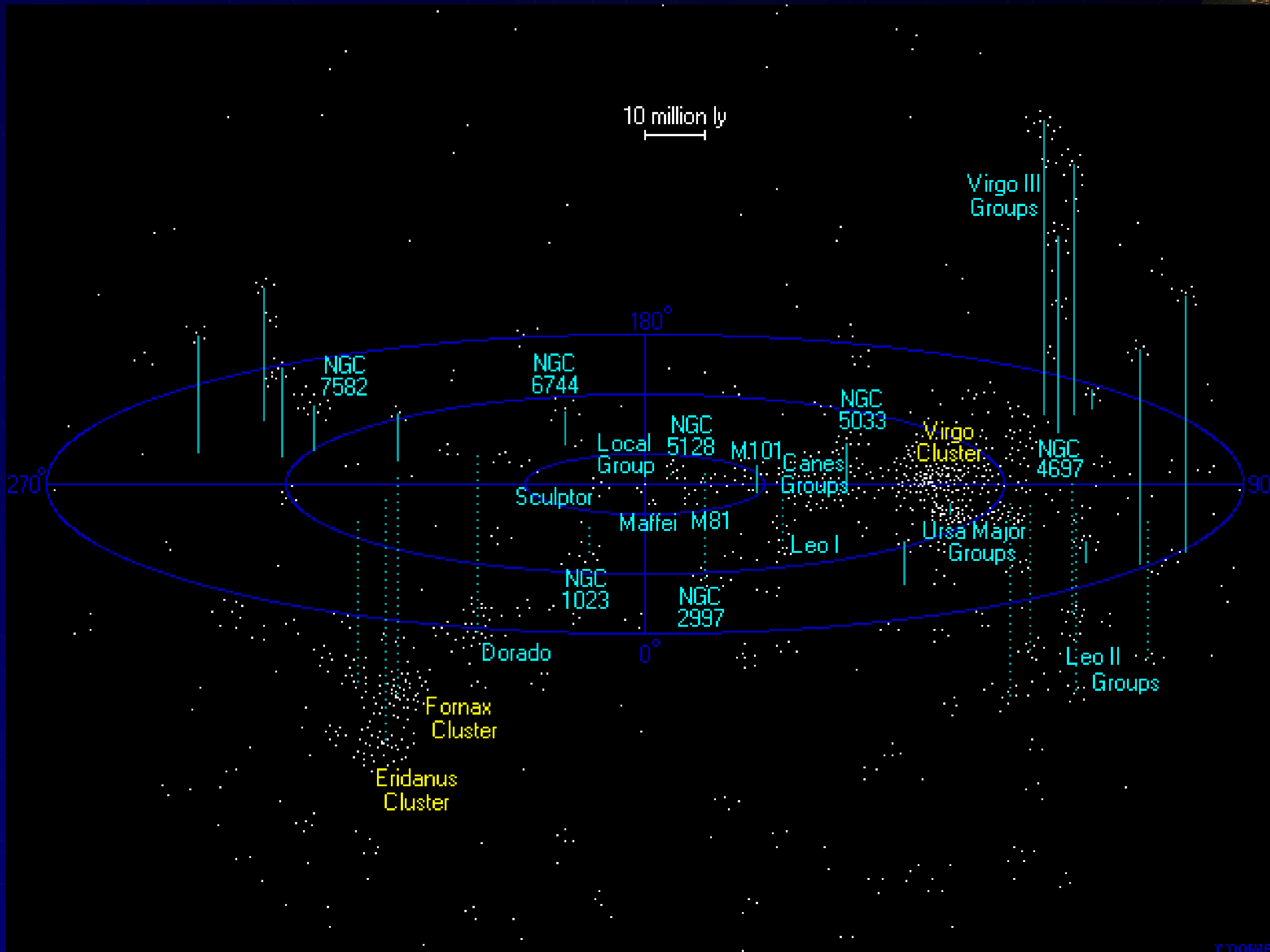
Large scale structure

- How did the structures we see today form and evolve?
- Do cosmological models predict this behavior?
- Can they give us any insight into how and why this structure develops?



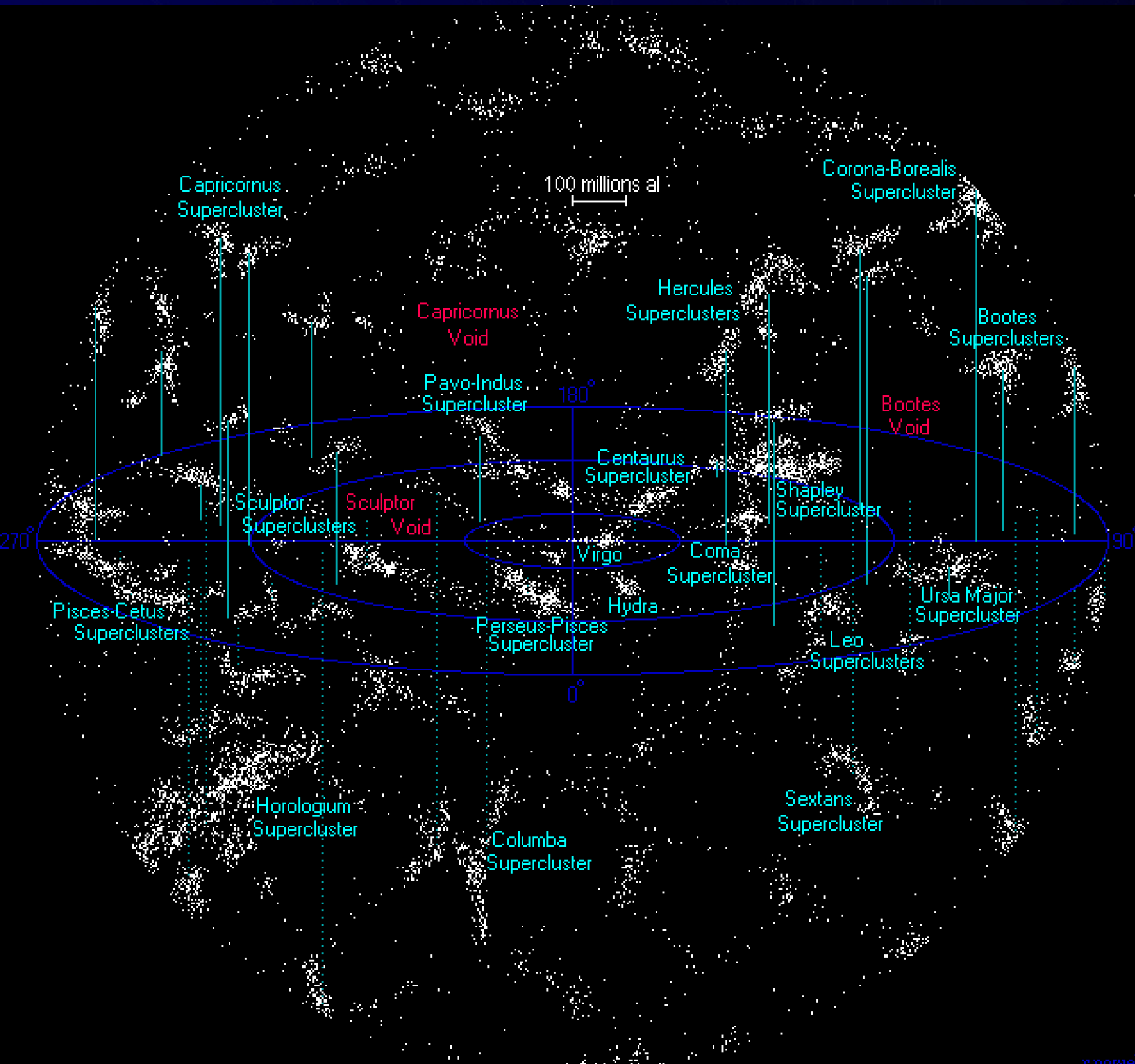


Large scale structure < 50 Mlyr



Atlas of the Universe

Large scale structure < 1 Glyr

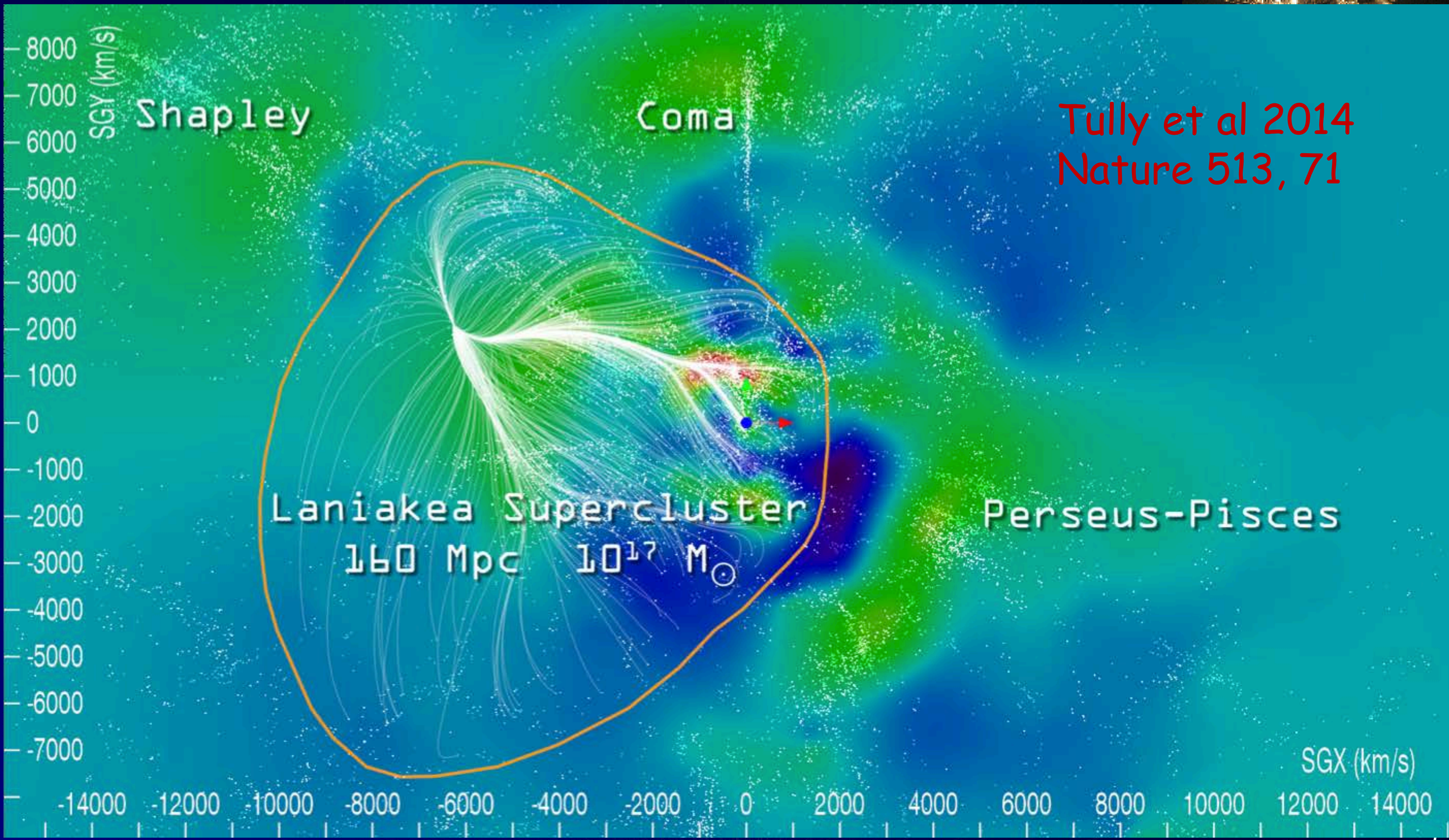


Pisces-Perseus Supercluster

"A Metagalactic Cloud between Perseus and Pegasus" Bernheimer (1932 Nature)

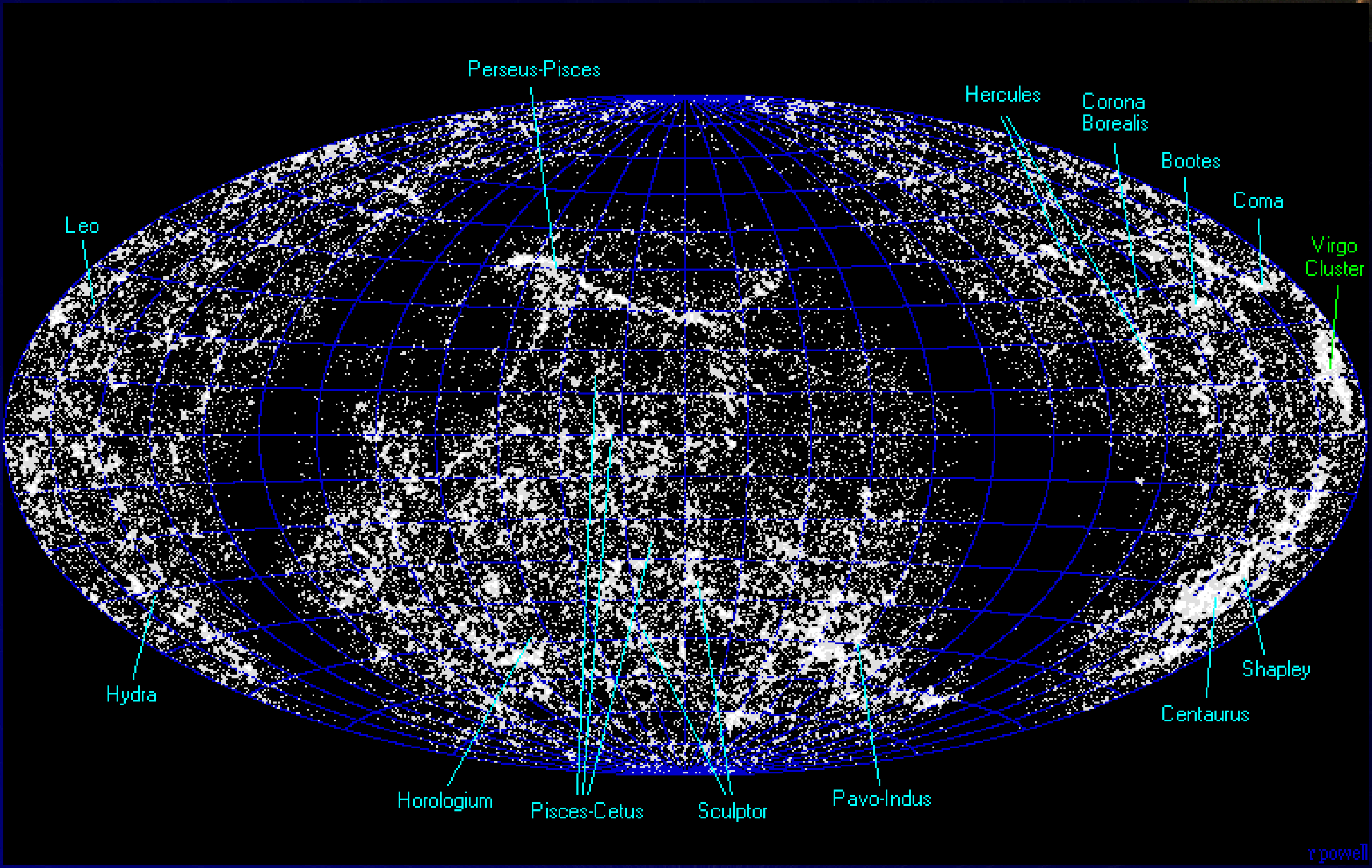
Atlas of the Universe

The Pisces-Perseus Supercluster



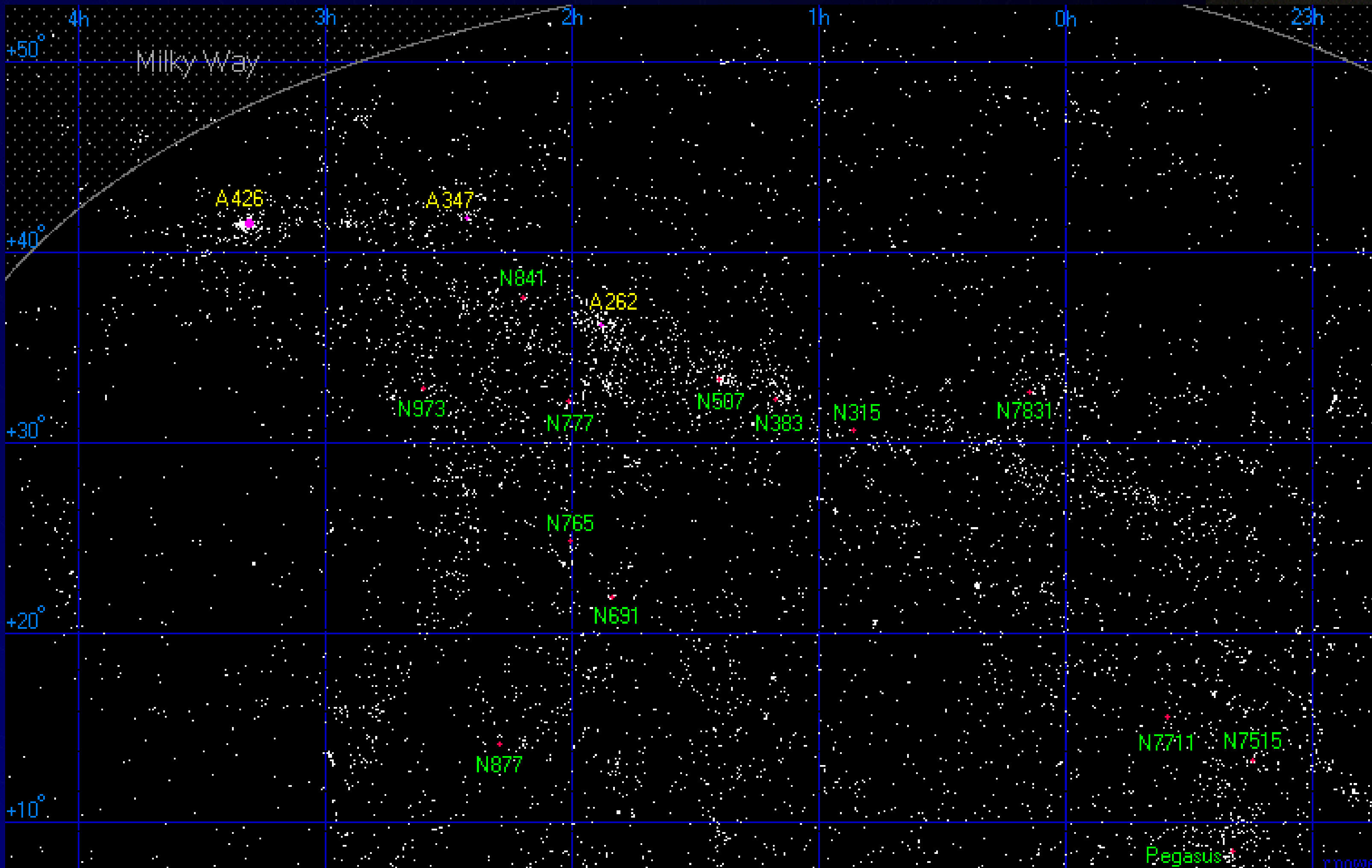
Tully *et al* 2014 Nature

The Pisces-Perseus Supercluster



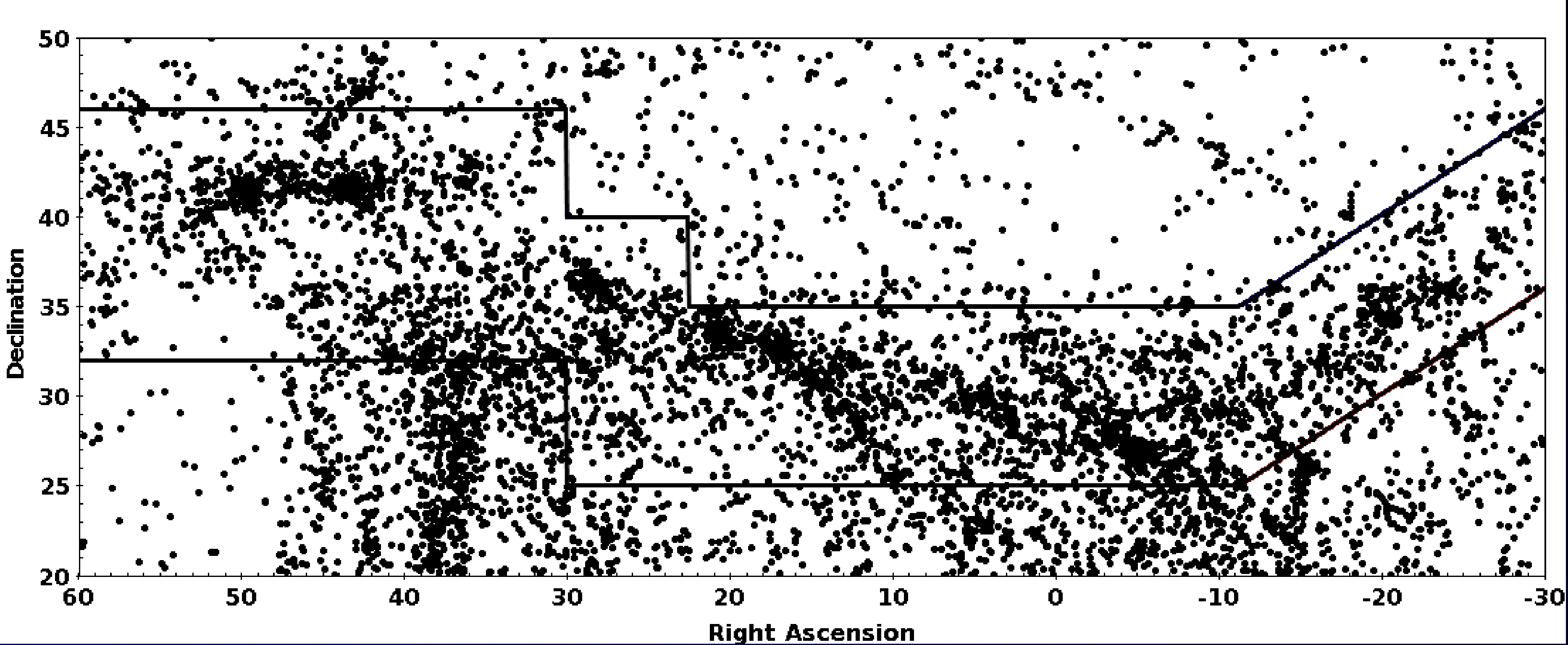
Atlas of the Universe

The Pisces-Perseus Supercluster



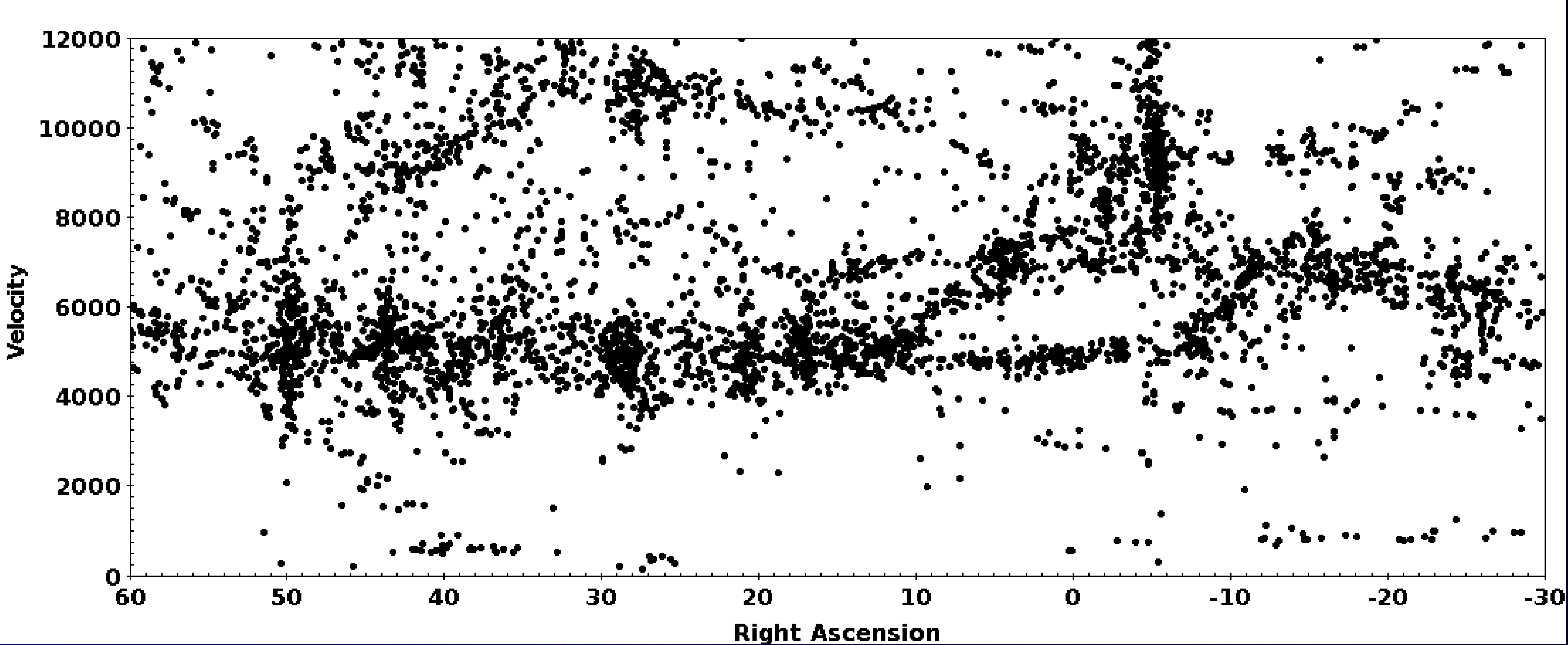
Atlas of the Universe

The Pisces-Perseus Supercluster



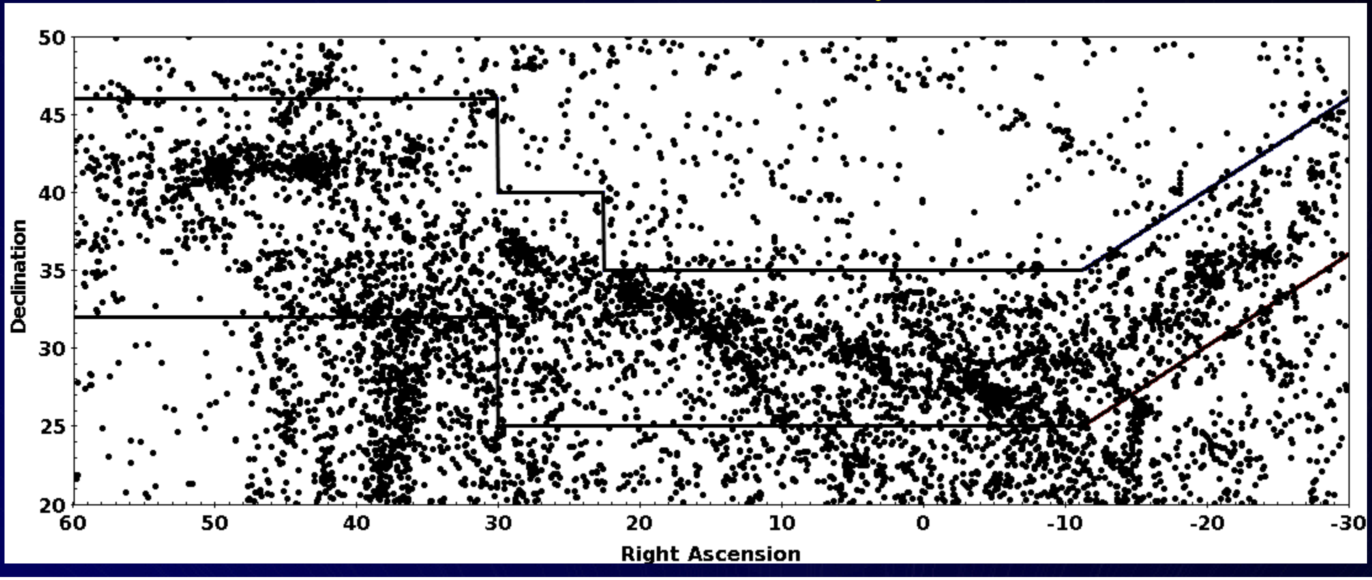
See SH#1

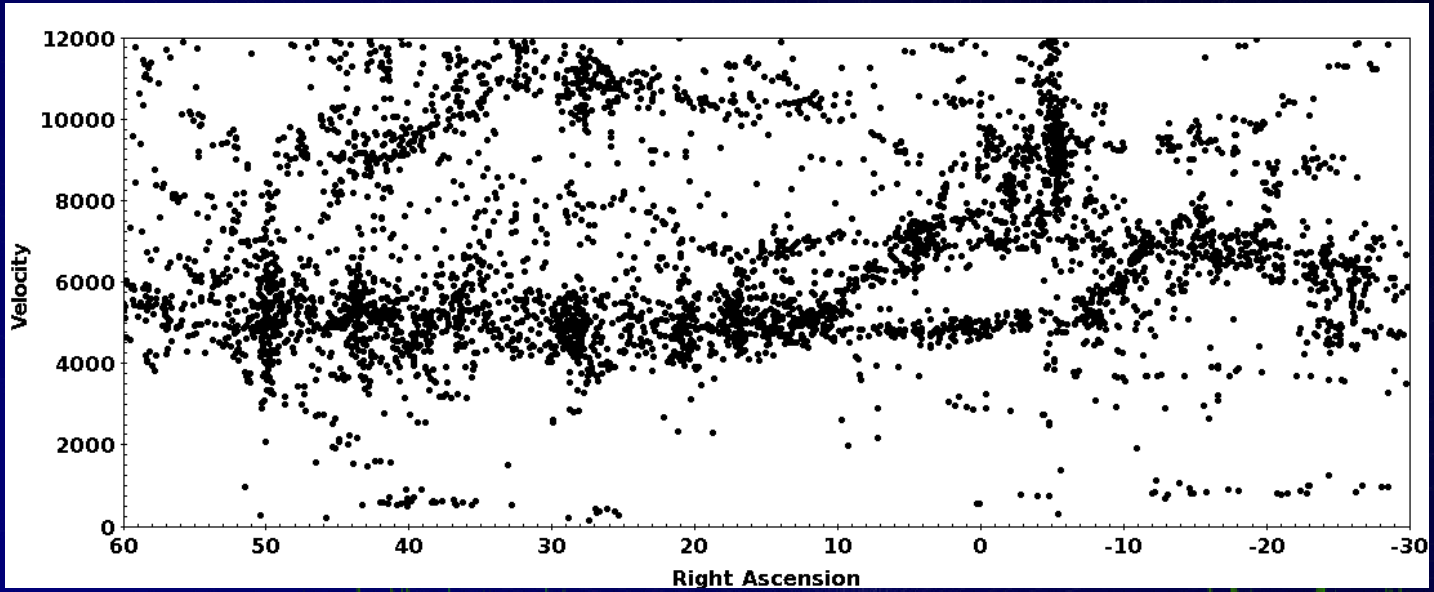
The Pisces-Perseus Supercluster



See SH#1

The Pisces-Perseus Supercluster



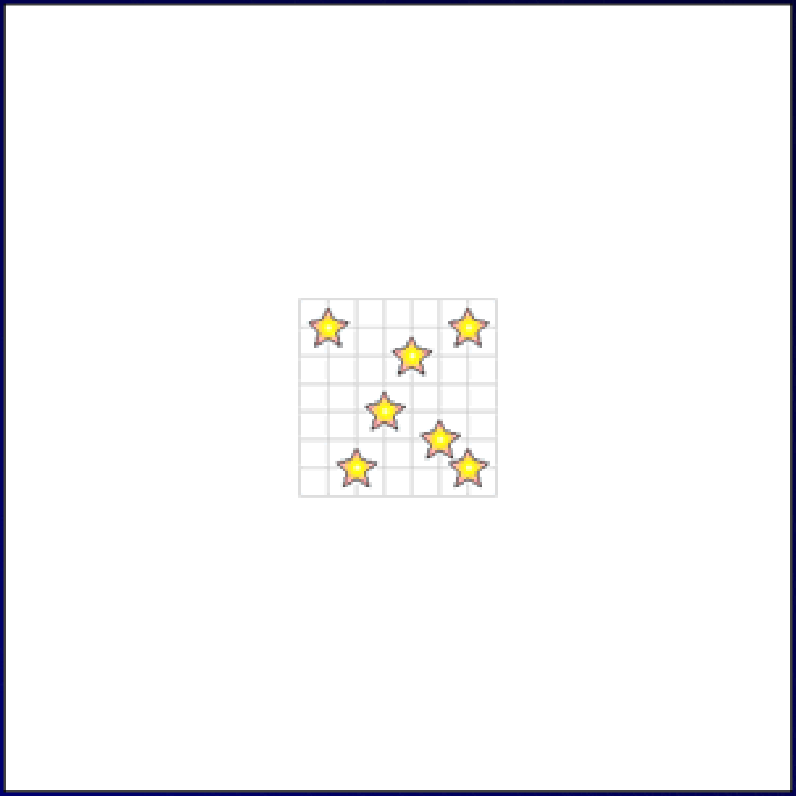


Main clusters/groups in PPS

Name	Common Name	R.A.(J2000) (deg)	Dec(J2000) (deg)	cz (km/s)
N7343	Pegasus	339.7	34.0	6000.
Abell 2634		354.6	27.0	9400.
Abell 2666	Pegasus	357.7	27.2	8000.
N 383	Pisces	16.9	32.4	4800.
N 507		20.5	33.3	4700.
Abell 262		28.2	36.2	4800.
Abell 347		36.5	41.9	5600.
Abell 426	Perseus	49.7	41.5	5500.

See SH#1

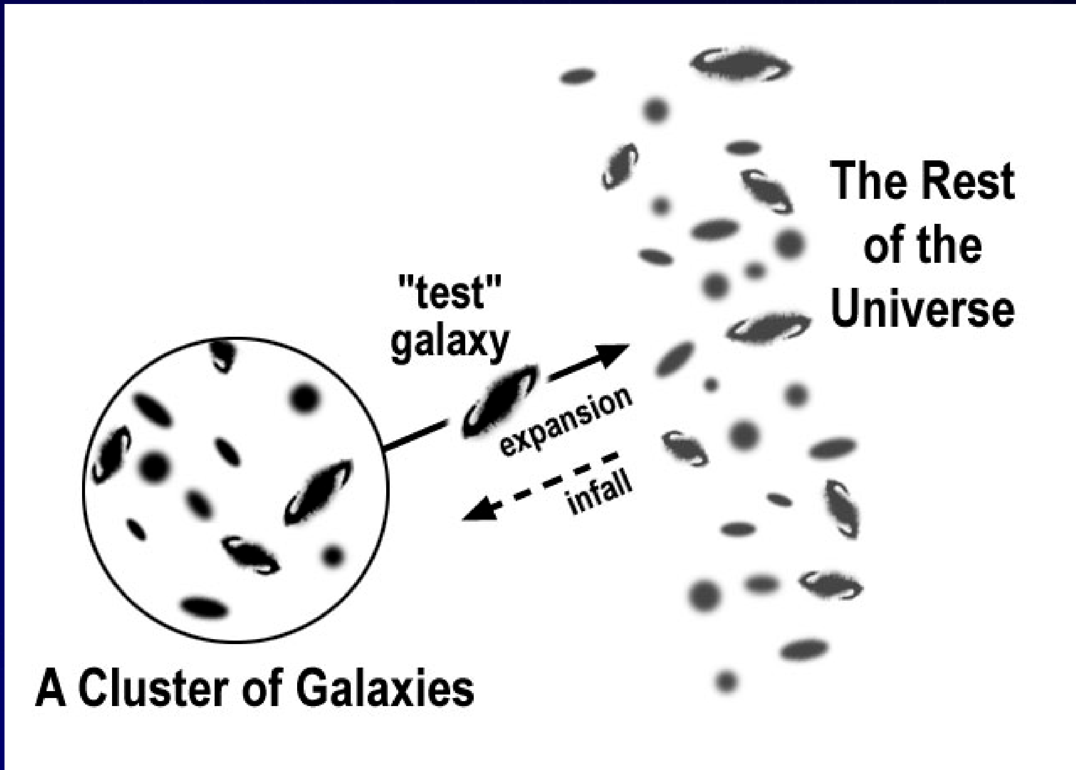
Smooth Hubble Flow



- The dominant motion in the universe is the smooth expansion, known as the Hubble Flow.

- Cosmological principle: On large scales, the universe is homogeneous and isotropic.

Deviations from Hubble Flow



"Peculiar velocities"

$$V_{obs} = V_{Hubble} + Vpec$$

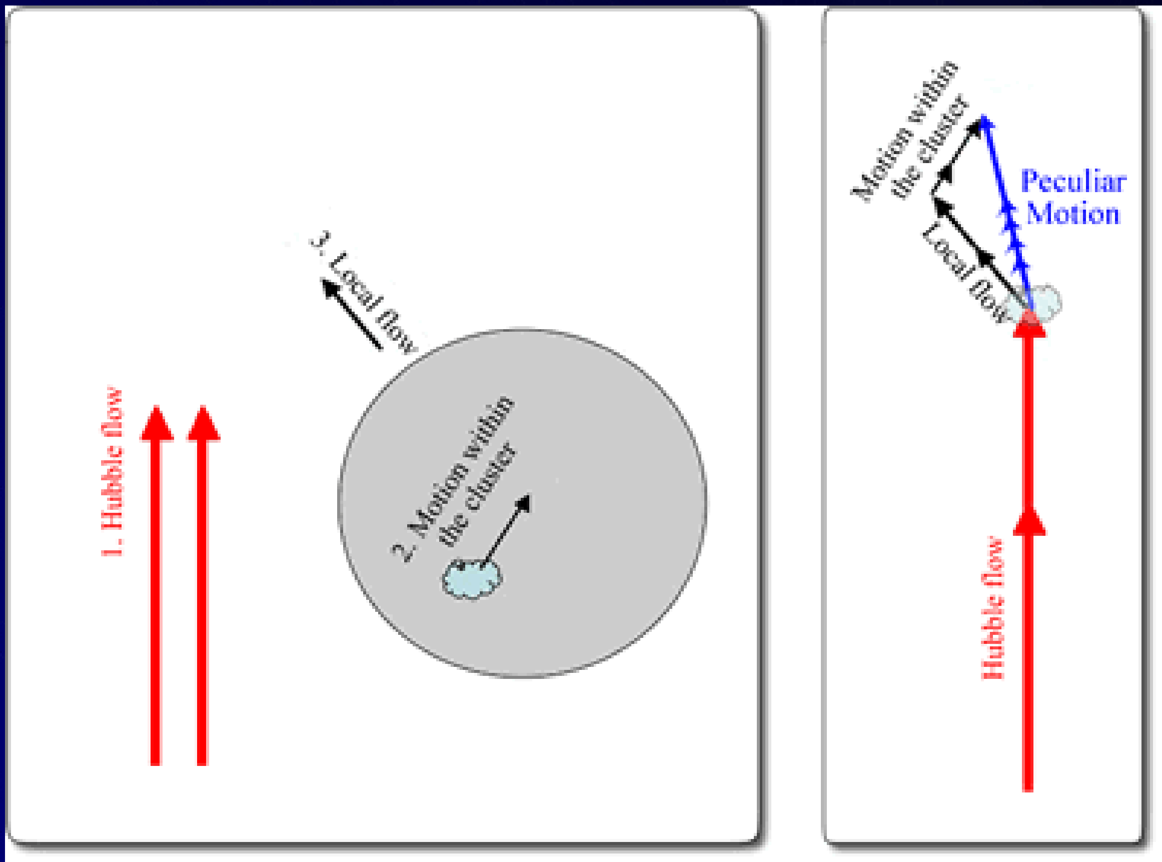
V_{pec} includes components of:

- Orbital motion in cluster/group
- Infall/outflow from regions of over/under-density
- "noise" on the pure Hubble flow

Trace V_{pec} ⇔ Trace mass

Tully *et al* 2014 Nature

Deviations from Hubble Flow



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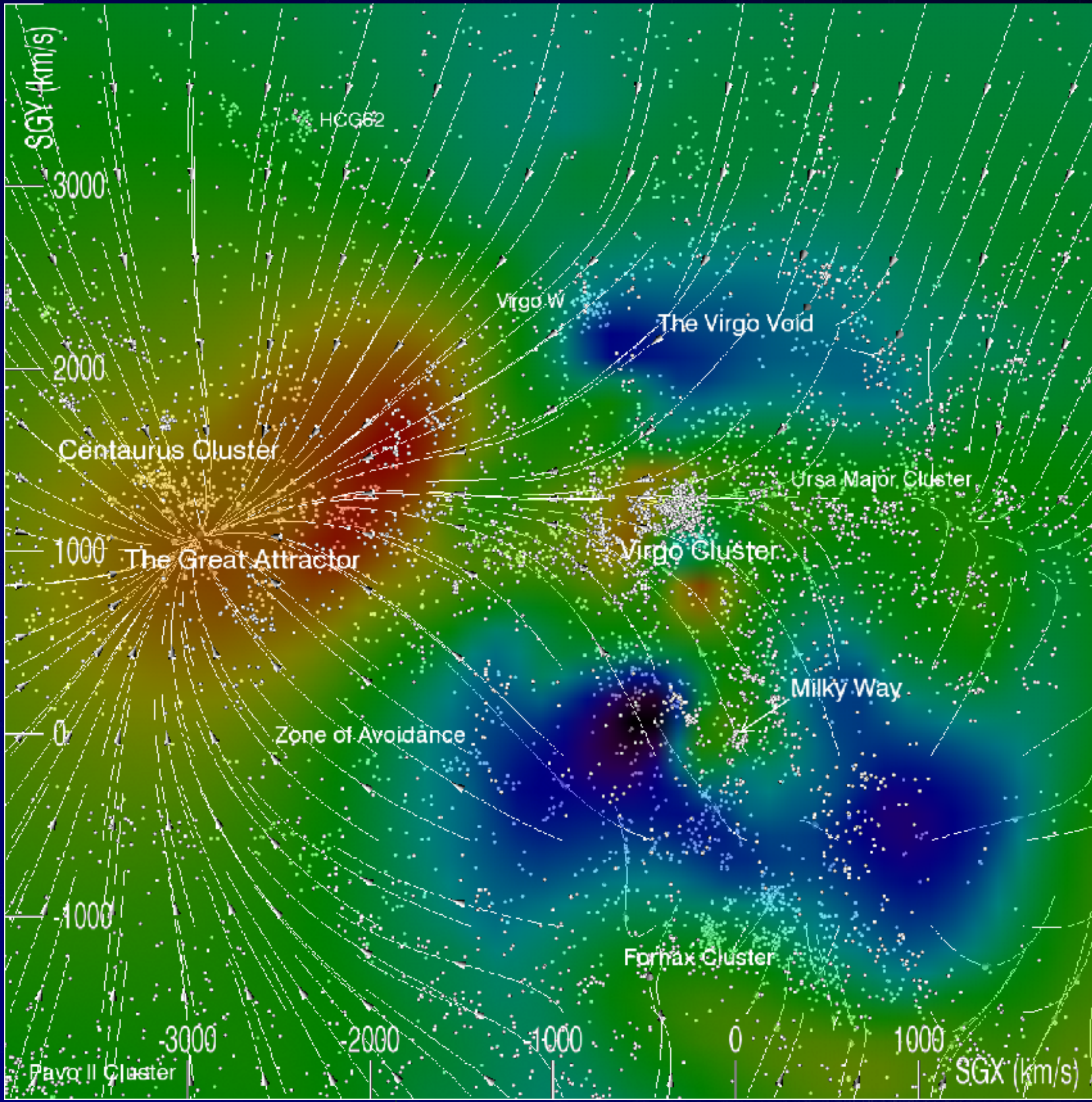
Tully *et al* 2014 Nature

"Peculiar velocity: field => mass



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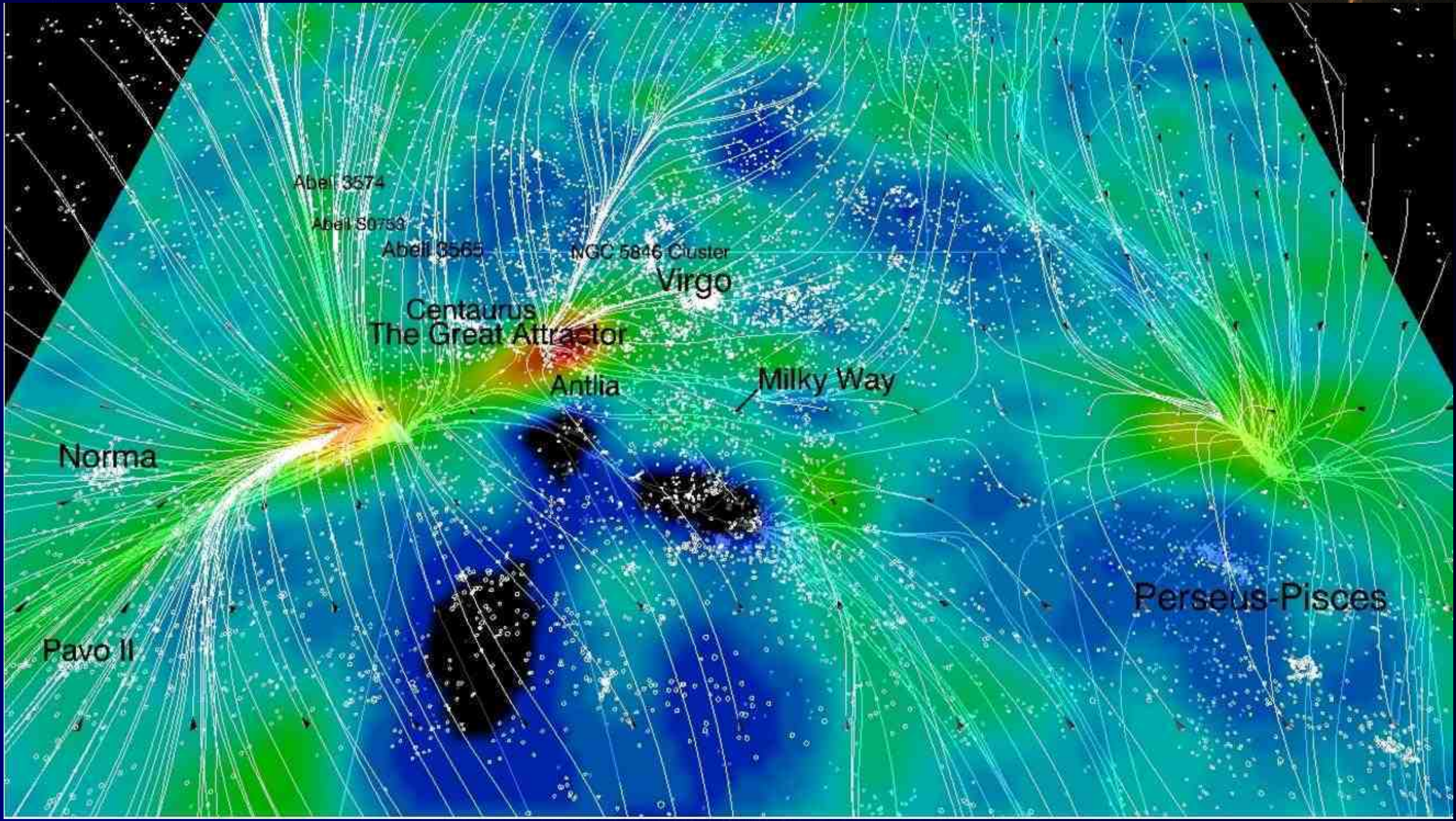
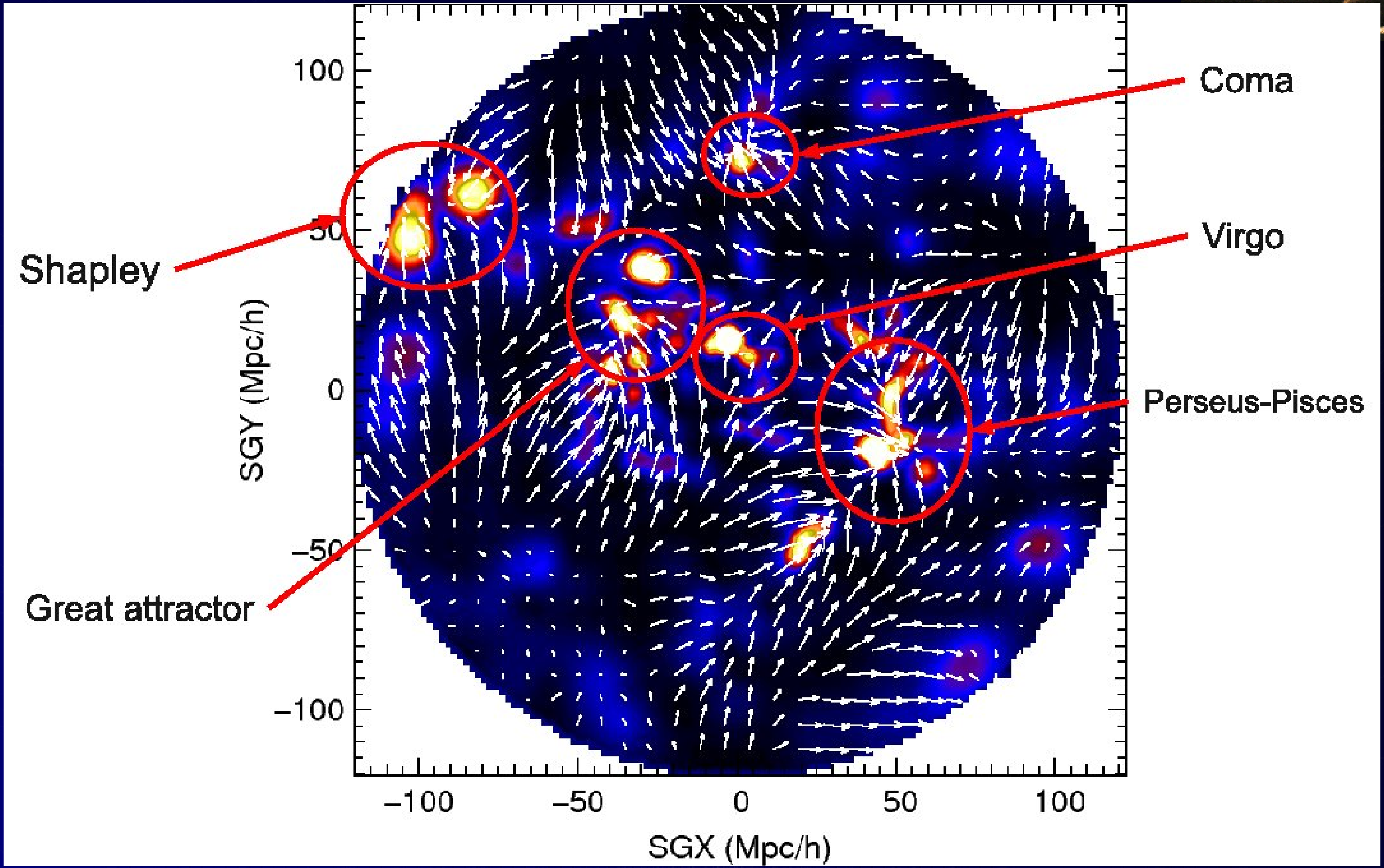
Tully *et al* 2014 Nature

The Pisces-Perseus Supercluster



Tully *et al* 2014 Nature

Velocity field from CosmicFlows



Measuring peculiar velocities?

"Peculiar velocities"

$$V_{obs} = V_{Hubble} + V_{pec}$$

$$V_{Hubble} = H_o D$$

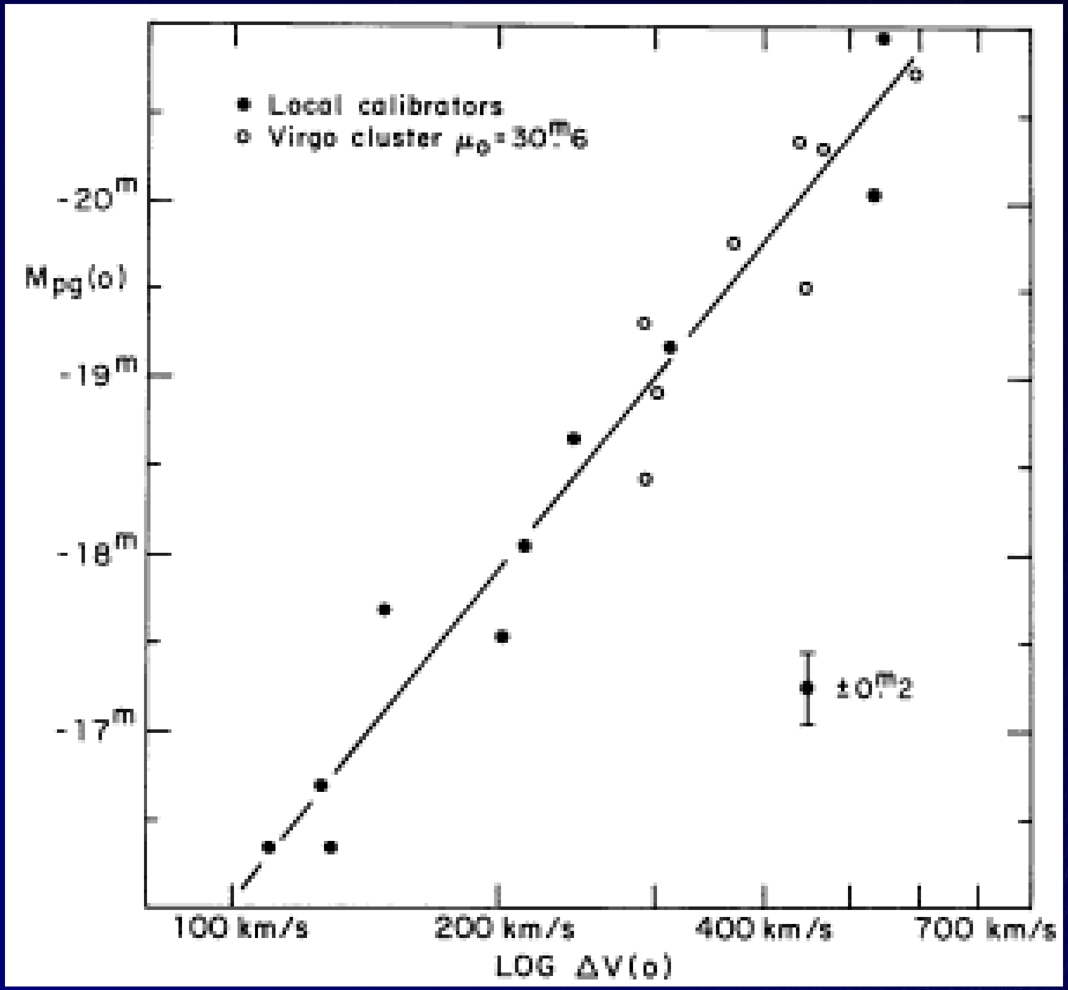
$$V_{pec} = V_{obs} - H_o D$$

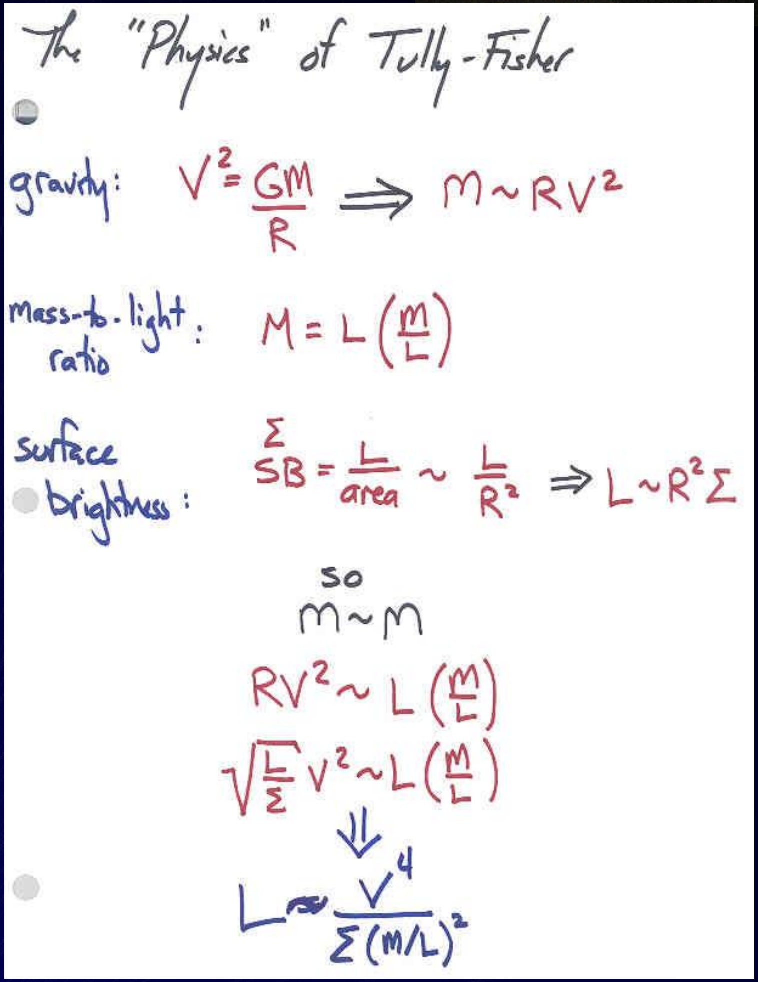
- Observe the recessional velocity
- Measure the distance by a redshift-independent method
- Estimate the Hubble velocity expected for a galaxy at that distance.
- The difference between the observed and expected recessional velocity is the peculiar velocity.

The method we use to estimate the distance depends on:

- the type of galaxies we study;
- their distance from us;
- how accurate we need the distance to be;
- the investment of telescope time needed to achieve the result.

Tully-Fisher relation

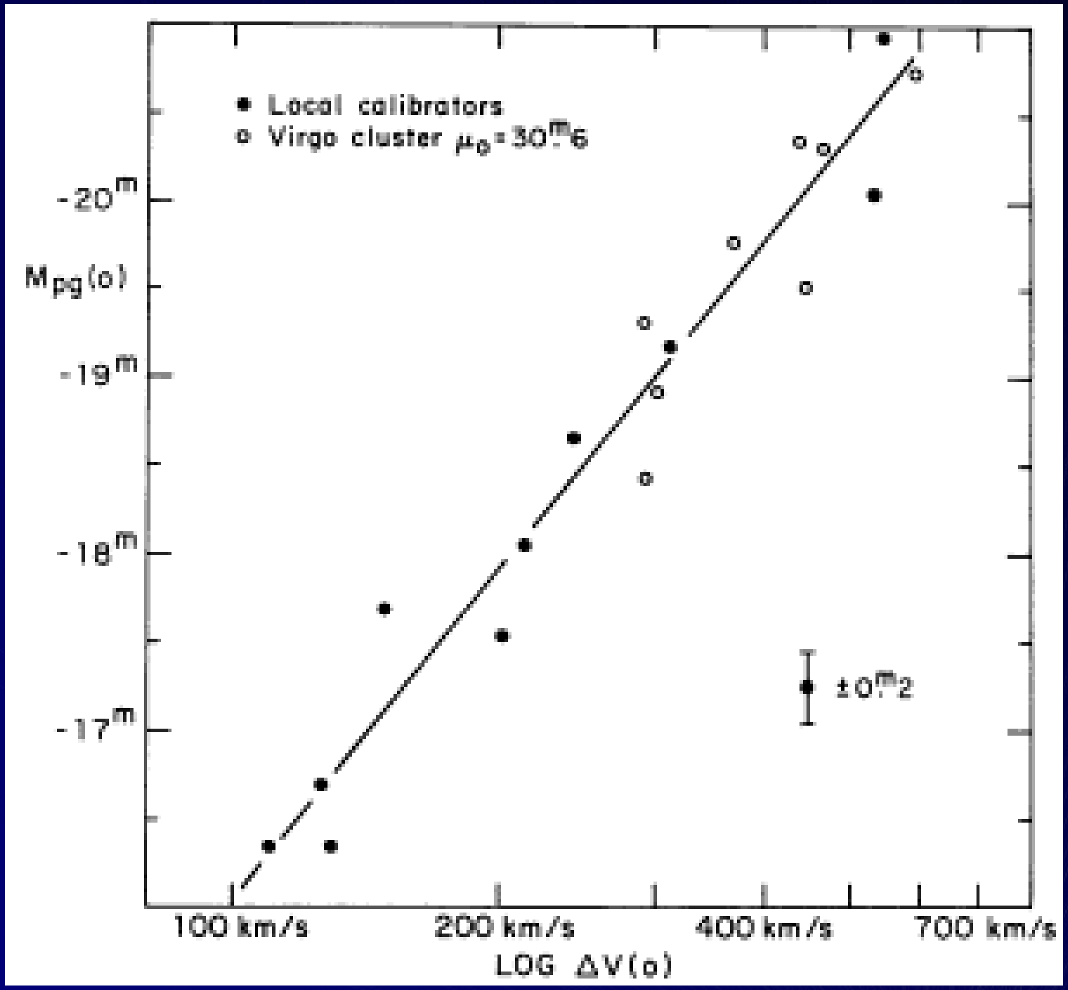




Tully & Fisher, 1977, A&A 54, 661

http://burro.astr.cwru.edu

Tully-Fisher relation



$$L \sim \frac{V^4}{\Sigma (M/L)^2}$$

<u>if:</u> $\Sigma (M/L)^2 = \text{constant}$

$L \sim V^4$ — since $M \sim -2.5 \log L$

$M \sim -10 \log V$

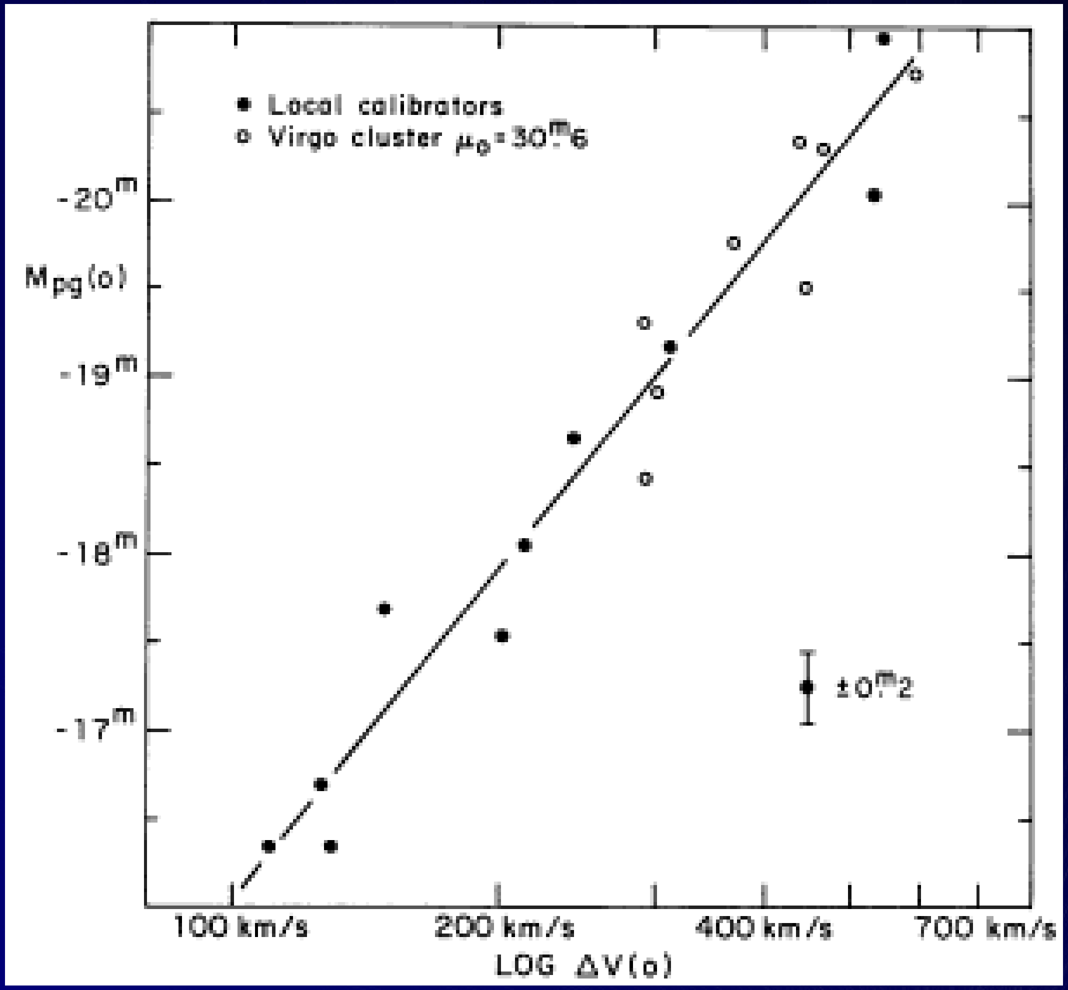
↑ mag, not mass

- is it reasonable that $\Sigma \sim$ constant?
- is it reasonable that $(M/L) \sim$ constant?
- is it reasonable that $\Sigma (M/L)^2 \sim$ const?

Tully & Fisher, 1977, A&A 54, 661

http://burro.astr.cwru.edu

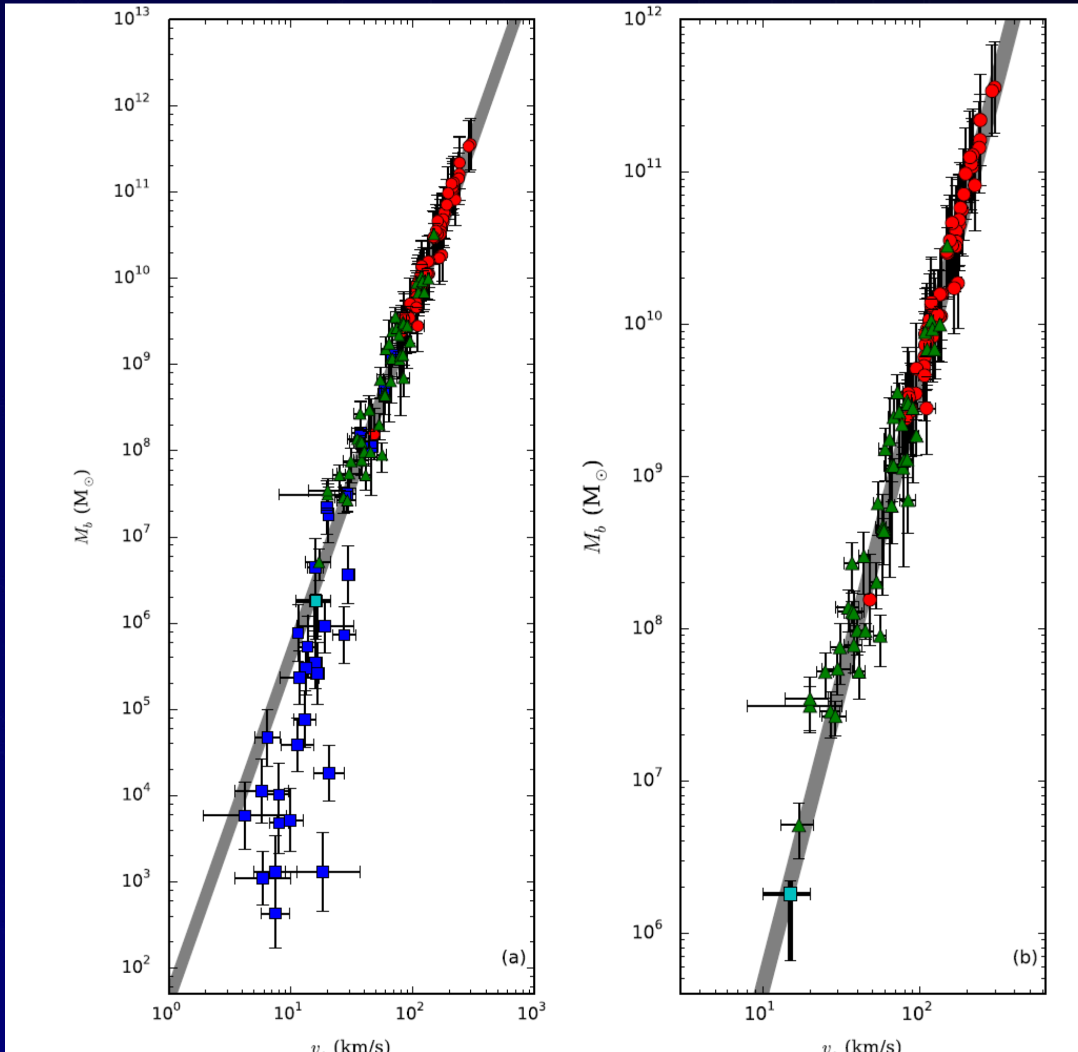
Tully-Fisher relation



Tully & Fisher, 1977, A&A 54, 661

- Observe the HI 21 cm emission profile:
  - Measure V_{obs}
  - Measure W_{obs} (width of 21 cm profile)
- Obtain an image of the galaxy
  - Measure total brightness (apparent magnitude m)
  - Measure the apparent axial ratio b/a
- Make lots of corrections to get rotational velocity and absolute magnitude
- Use TFR to get distance

The Baryonic Tully-Fisher Relation

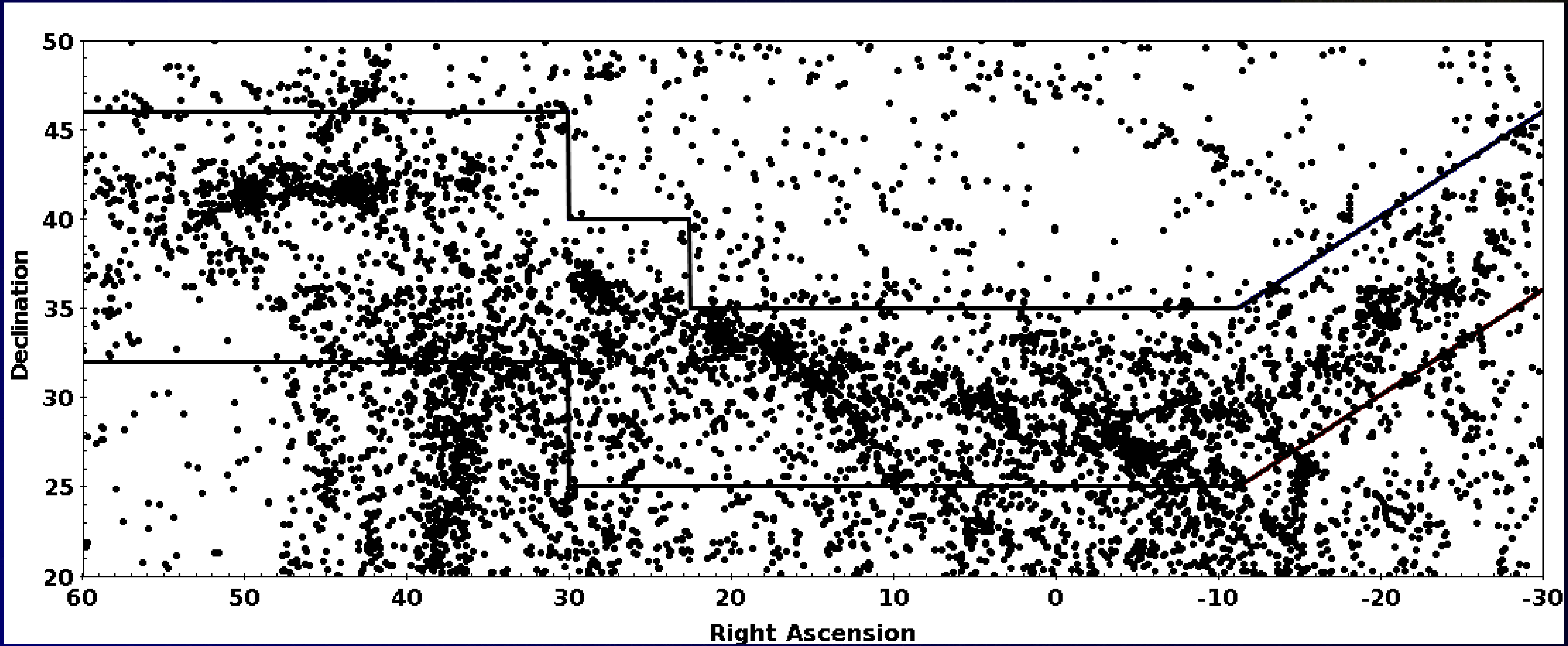


- Recent works substitute stellar mass for absolute magnitude.
- For star-forming galaxies of stellar masses below 10^9 $M_\odot$ the HI mass exceeds the stellar mass.
- Define the baryonic mass as the sum of the stellar and HI masses.

Note: some authors correct for He or H_2 abundance; watch definition!

Bernstein-Cooper, Cannon et al 2014 AJ 148, 35

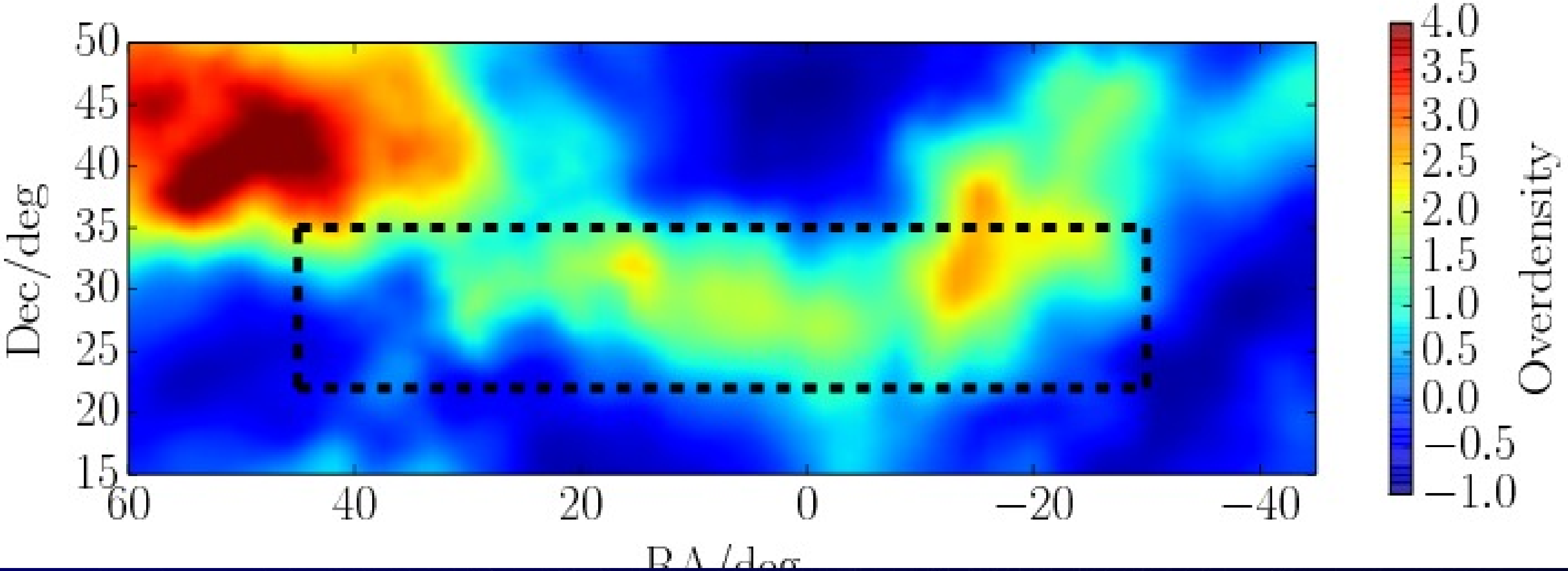
The Pisces-Perseus Supercluster



See SH#1

The Arecibo Pisces-Perseus Supercluster Survey

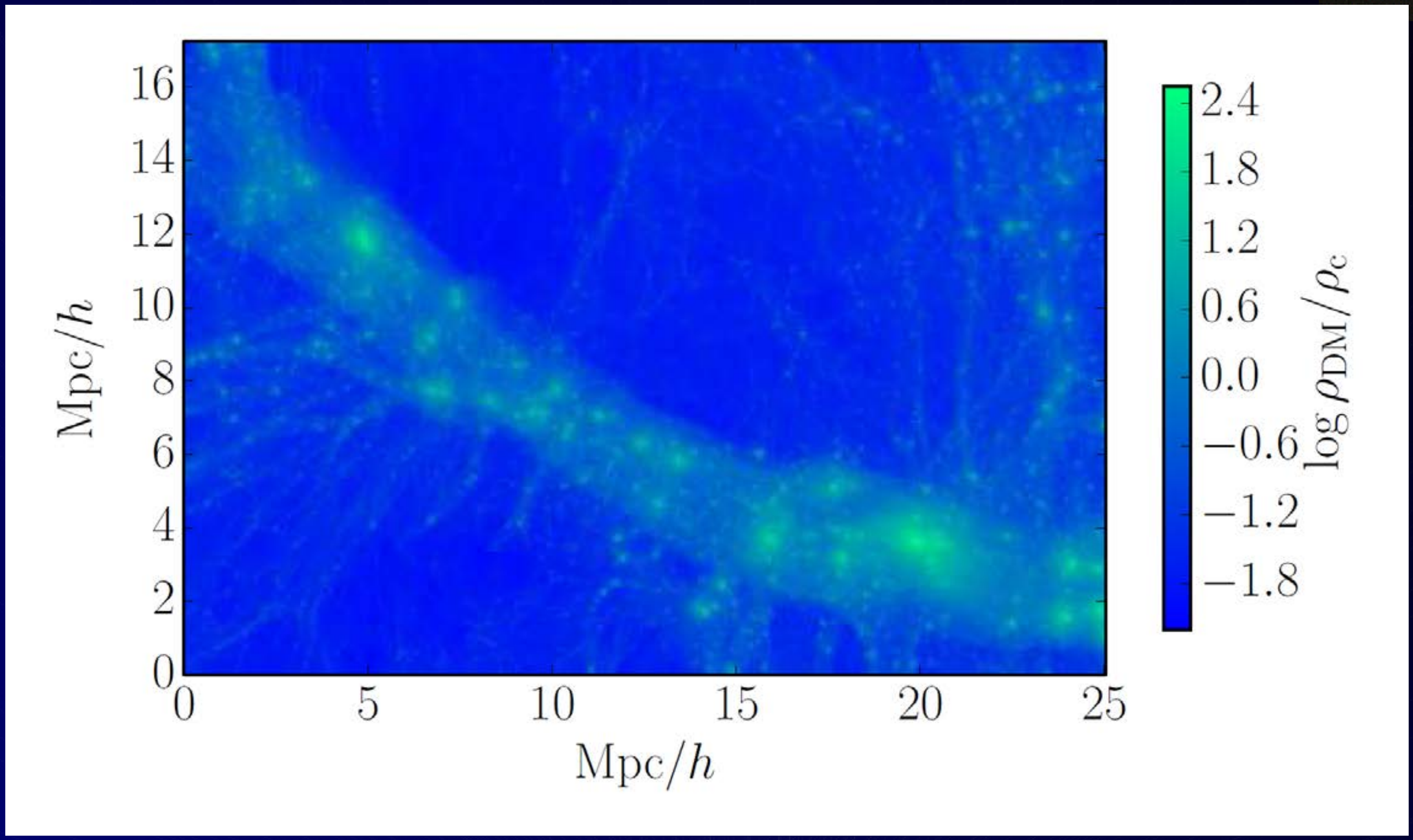
The APPS survey or the APPSS



Mean overdensity over the v_{Helio} range (4000,8000) produced by interpolating between 2MRS overdensity map points (Erdogdu+ 2006)

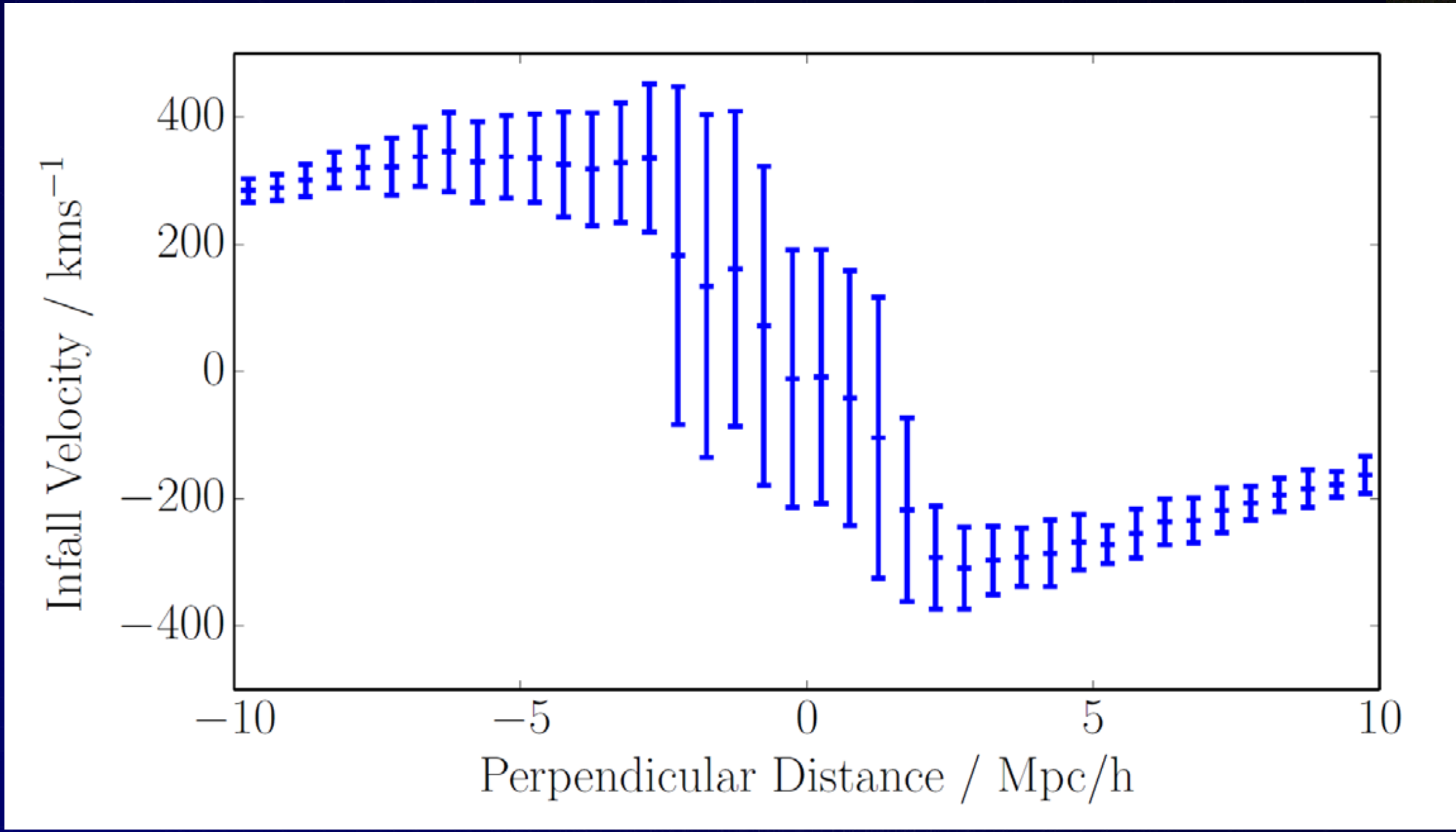
The black dotted rectangle outlines our target area:
22h < RA < 3h and +23 < Dec < +35

Filaments in the Illustris Simulation



Here is an example of a filament in the Illustris simulation (it is actually smaller and of lower ovensity than PPS.

Filaments in the Illustris Simulation



Here is the expected infall and backflow around that filament.

APPSS Survey Objective

- Measure BTFR distances and peculiar velocities to a large sample of galaxies in the PPS
- Look for infall and backflow onto the PPS overdensity
- Measure the mass per unit length of the supercluster.
- Compare the result to the predictions of numerical simulations.

Measuring Infall onto PPS

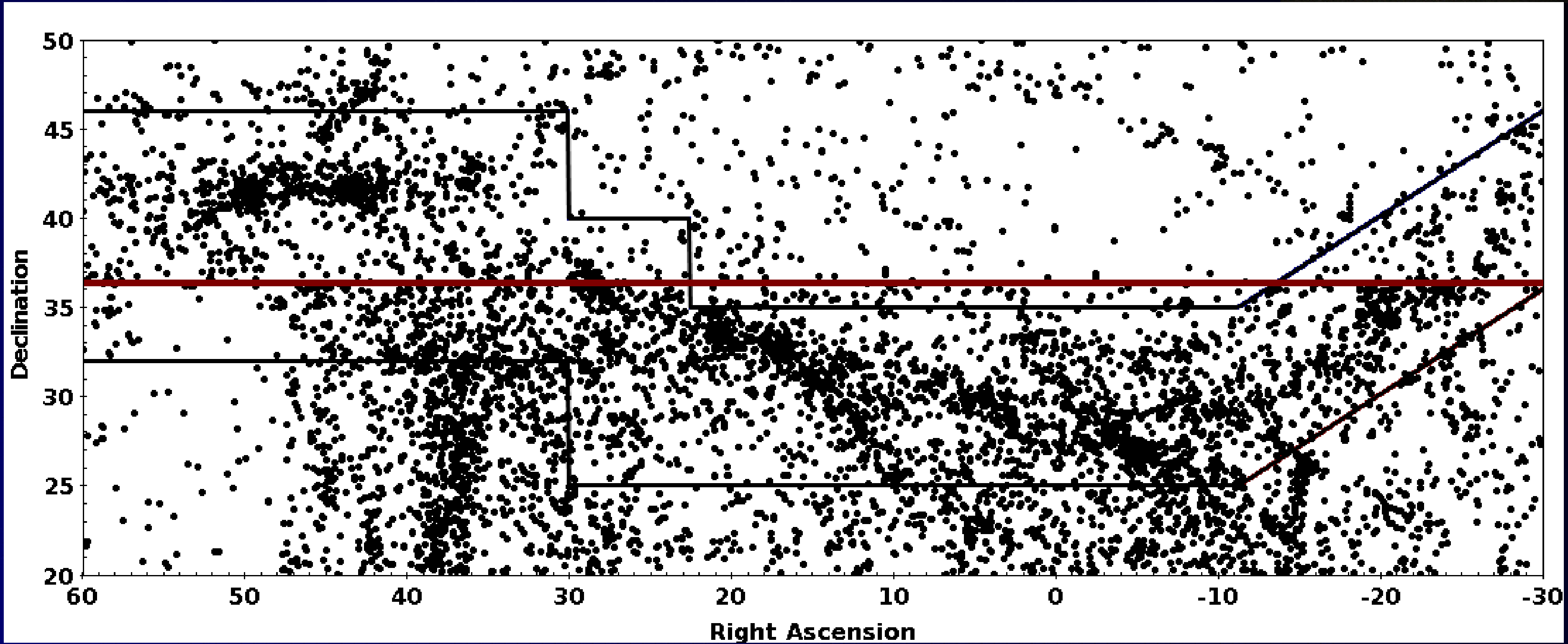
- Peculiar velocity measurements are tricky because of all the corrections that have to be made.
- The uncertainty in the BTFR distance on an individual galaxy is probably 25-30%. For a distance of 5000 km/s, that is a velocity error of > 1000 km/s!
- We need to be able to average/bin galaxies to reduce the uncertainty.
- We need more galaxies with BTFR distances!
- Comparison with simulations will allow us to place limits on the results, in the presence of uncertainty, sample bias, and statistics.

APPSS LBW Arecibo efforts

- Explore fainter SDSS/GALEX objects which are very blue and have sample range of AbsMag, r_d, SB => are they in the volume or not?
  - Identify PPS targets meeting SDSS spectroscopic sample and blue (NUV-r), but not in a.70
  - Conduct LBW survey of these targets (Fall 2015, 2016)
    - Measure HI flux densities, recessional velocities and velocity widths
  - Measure magnitudes and axial ratios of detections
    - Calculate stellar masses and inclinations
    - Calculate baryonic masses (stars+gas)
    - Calculate rotational velocities (corrected for inclination)

- Explore dependence of HIMF/WF across range of environments sampled
- Using BTFR to measure infall onto PPS ridge

The Pisces-Perseus Supercluster



See SH#1

GBT targets June '17