Introductory Astronomy

Week 7: Galaxies

Clip 13: Galaxy Clusters

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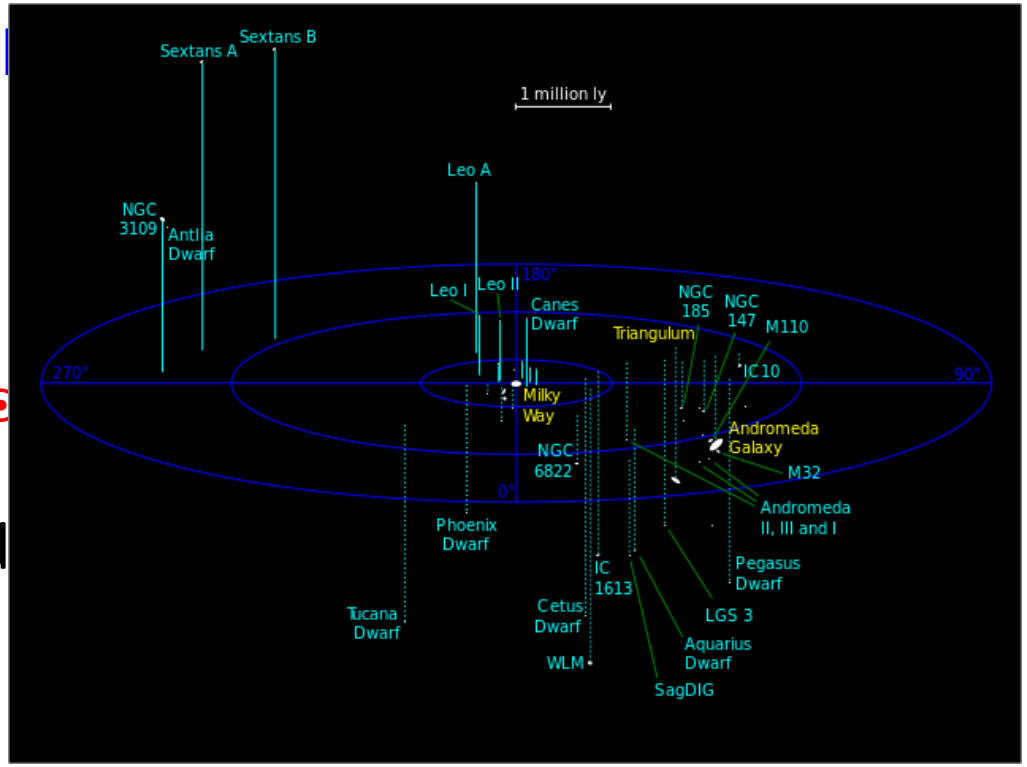
Our Cluster

- Milky Way is part of Local Group
- Three giant spirals of 35 mostly irregulars
- Estimate mass 4×10^{12} $M_{\odot}$ at most 10% baryonic
- Merger of Milky Way and M31 in 4Gy possible



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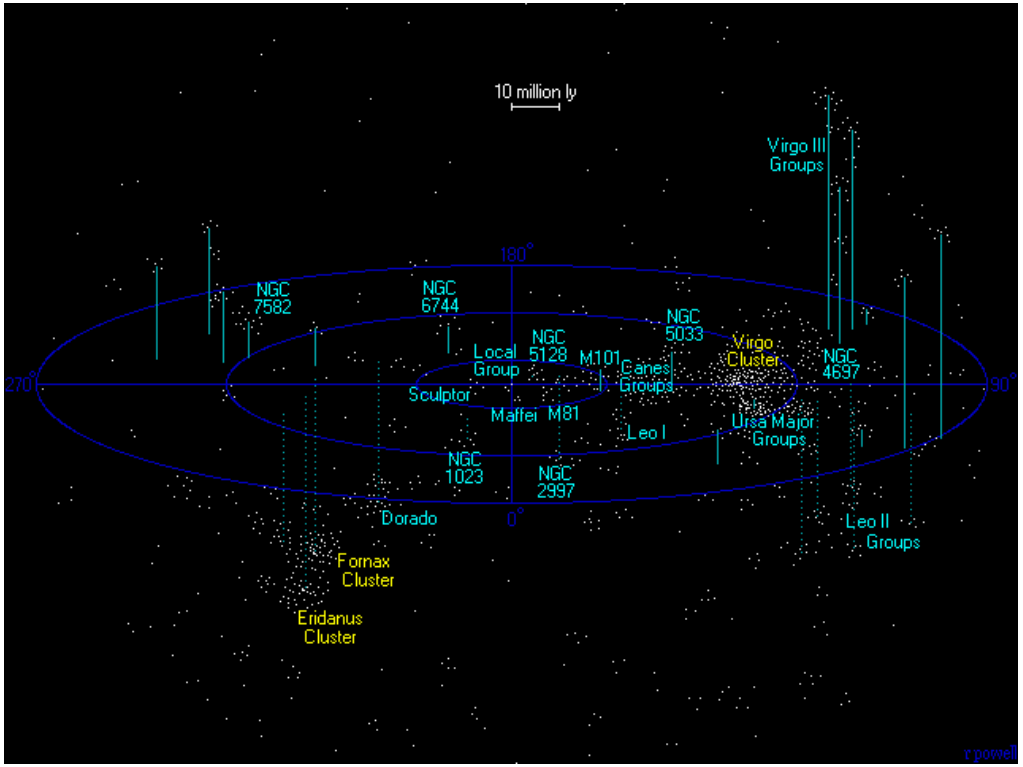
Virgo Cluster

- 250 large galaxies and over 2000 smaller ones 16Mpc
- 68% spirals 19% ellipticals including four giants radius 1-300kpc



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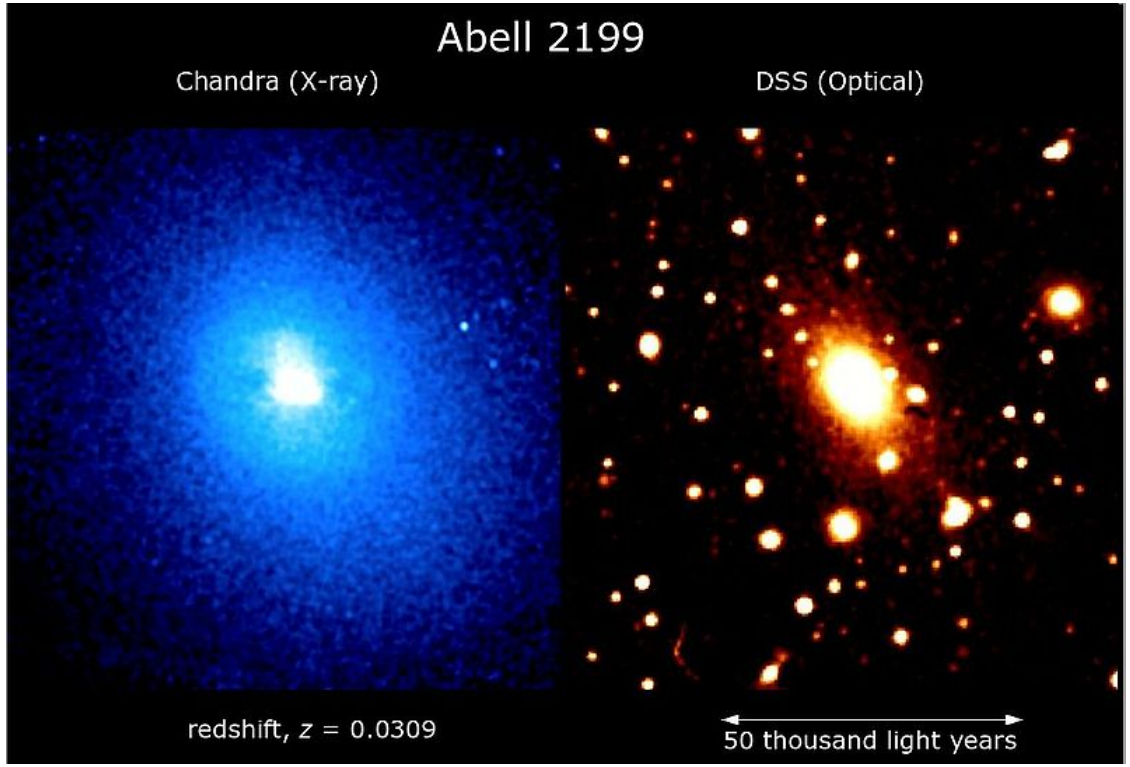
Full of Hot Gas

- Intracluster medium of hot 10^6K gas contains 8× more mass than galaxies
- Intergalactic stars may account for 10% of mass



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Dark Matter in Clusters

- Gravitational lensing by clusters can be used to find mass distribution of lens

$$\theta = \frac{4GM}{rc^2}$$

- Find most of the mass is in diffuse dark matter

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Bullet Cluster

- In collisions between clusters hot gas is strongly interacting while galaxies interact weakly (gravitationally)
- Dark Matter interacts weakly so follows galaxies

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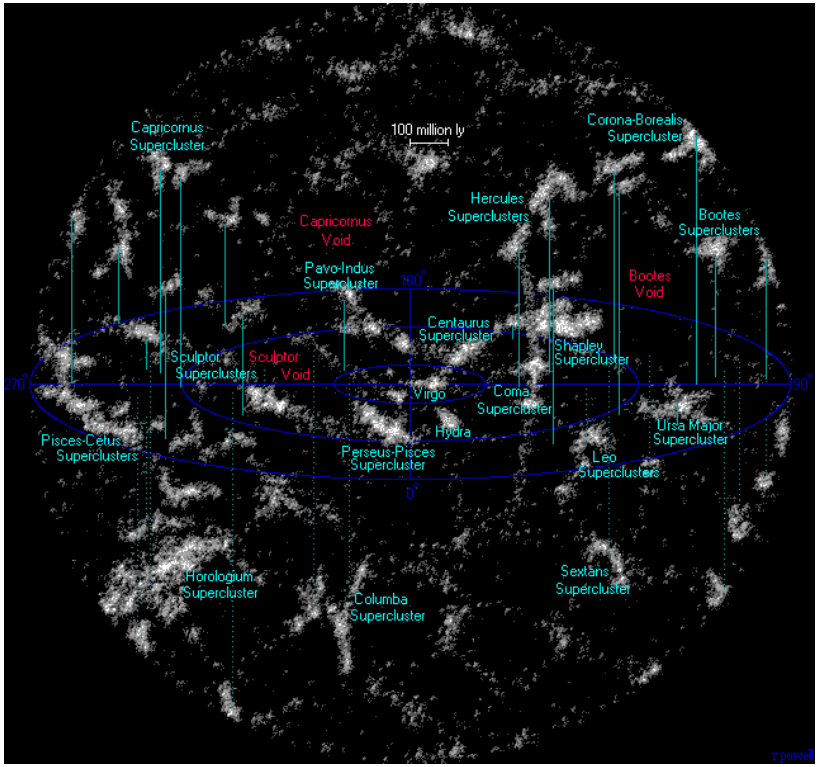
Superclusters

- Local Supercluster centered on Virgo with size 20Mpc
- More at larger distances
- Local peculiar motion relative to Hubble flow predicts Great Attractor in Centaurus



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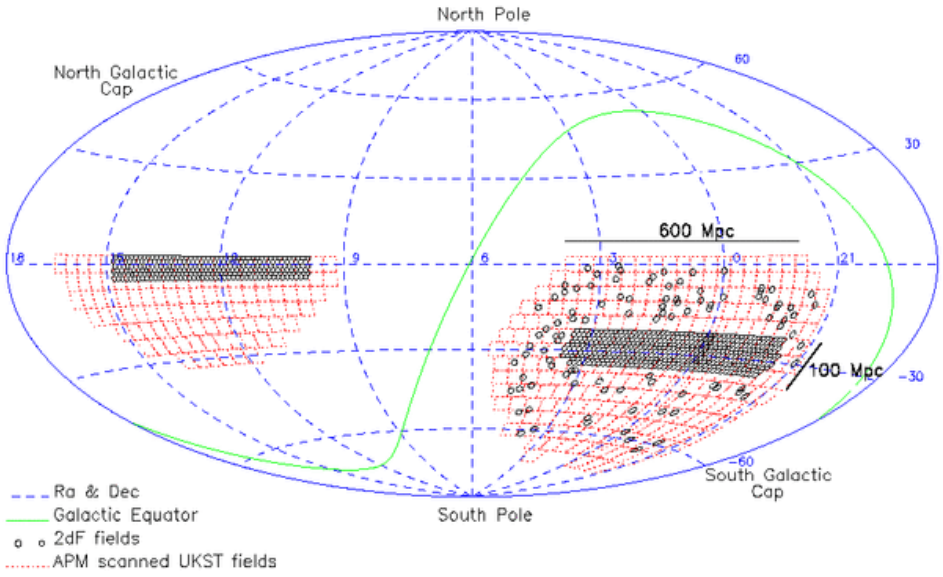
Structure at All Scales?

- Look for large-scale structure in two slices of sky avoiding Milky Way
- Map out to $z = 0.23$
- Find filamentary structure: sheets and voids



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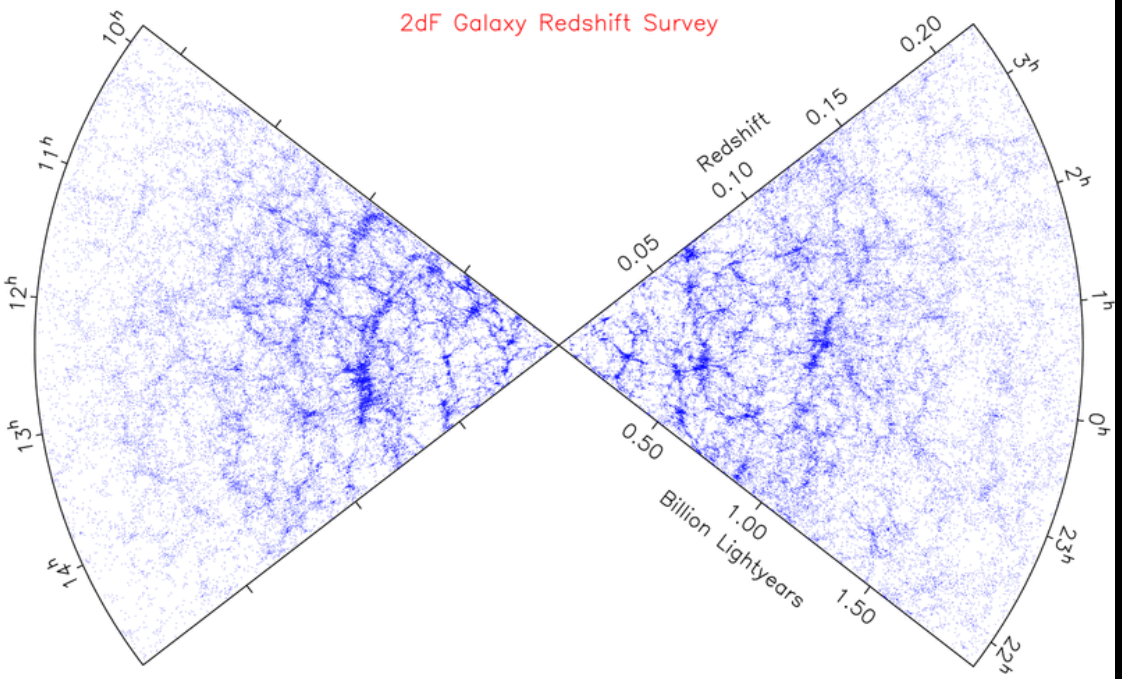
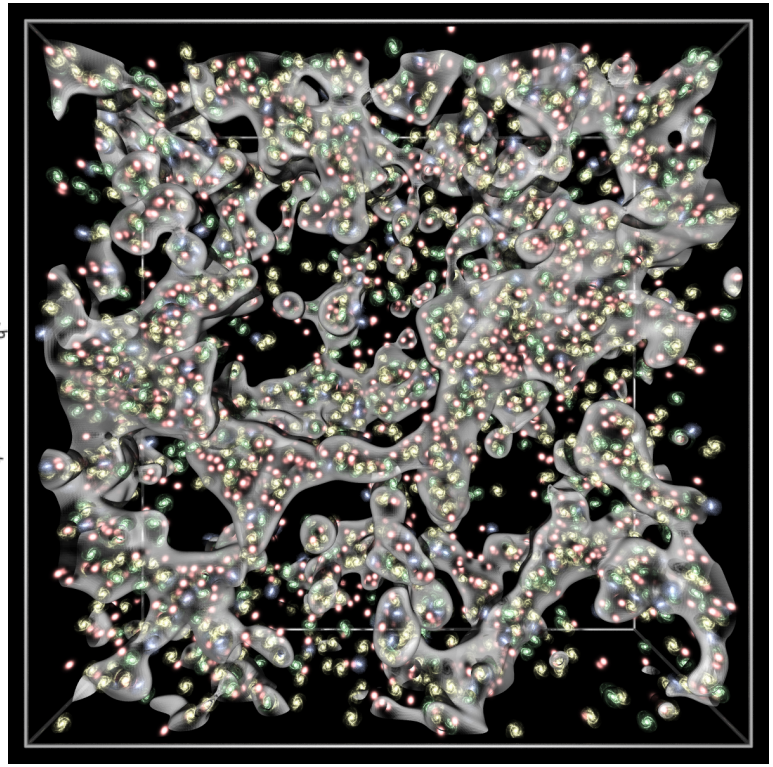
Large-Scale Structure





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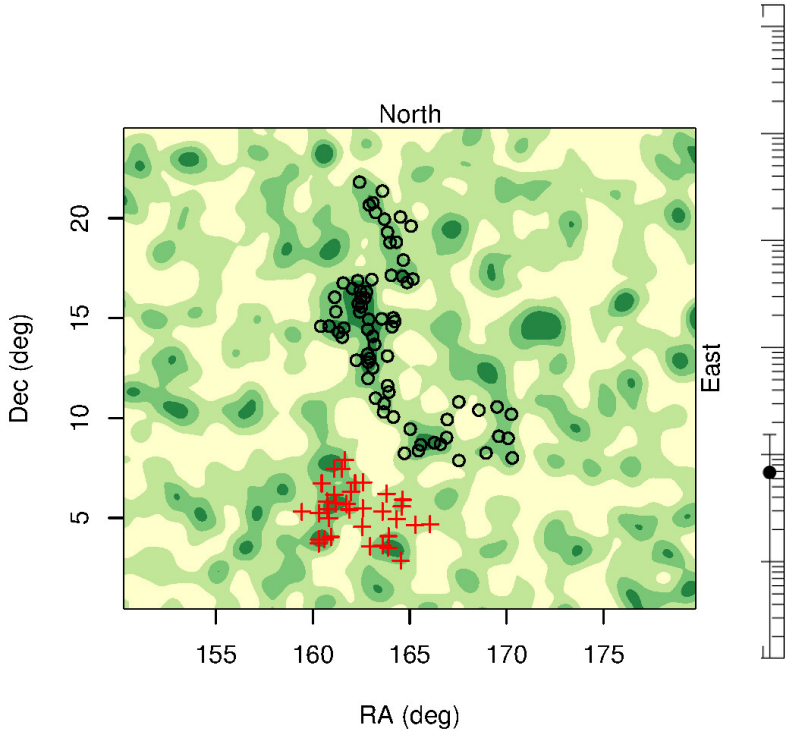
Limits to Structure

- Correlation data suggest at scales well above 100Mpc universe is homogeneous
- Size of voids means they are primordial. Could not have emptied since Big Bang
- 2012: Large Quasar Group >1Gpc across?



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Credits

- Local Group: R. Powell http://www.atlasoftheuniverse.com/localgr.html
- Virgo Cluster: R. Powell http://www.atlasoftheuniverse.com/virgo.html
- CL0024: NASA, ESA, M. J. Jee & H. Ford et al. (Johns Hopkins U.) http://apod.nasa.gov/apod/ap070516.html
- Lensing by CL0024: LSST http://www.lsst.org/lsst/science/scientist_dark_matter
- Bullet Cluster: X-ray: NASA/CXC/M.Markevitch et al. Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al. Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al. http://apod.nasa.gov/apod/ap080823.html
- 2dfGRS Results: http://www2.aao.gov.au/2dFGRS/
- LQG 2012: Royal Astronomical Society \