LARGE SCALE STRUCTURE & GALAXY EVOLUTION

This is a really nice subtitle for my presentation, yessss

HUBBLE'S LAW

$$V_r = H_0 d$$

- Objects at large distances appear to be universally receding from us (based on redshift)
- The more distance between us, the faster the recession
- Redshift actually due to cosmic expansion, not relative motion

HUBBLE'S LAW

$$V_r = H_0 d$$

- Useful for determining distances to galaxies *if* you have a good measure of V_r and H_0
- Reverse also true – we measure H_0 using galaxies of known distance

PECULIAR MOTION

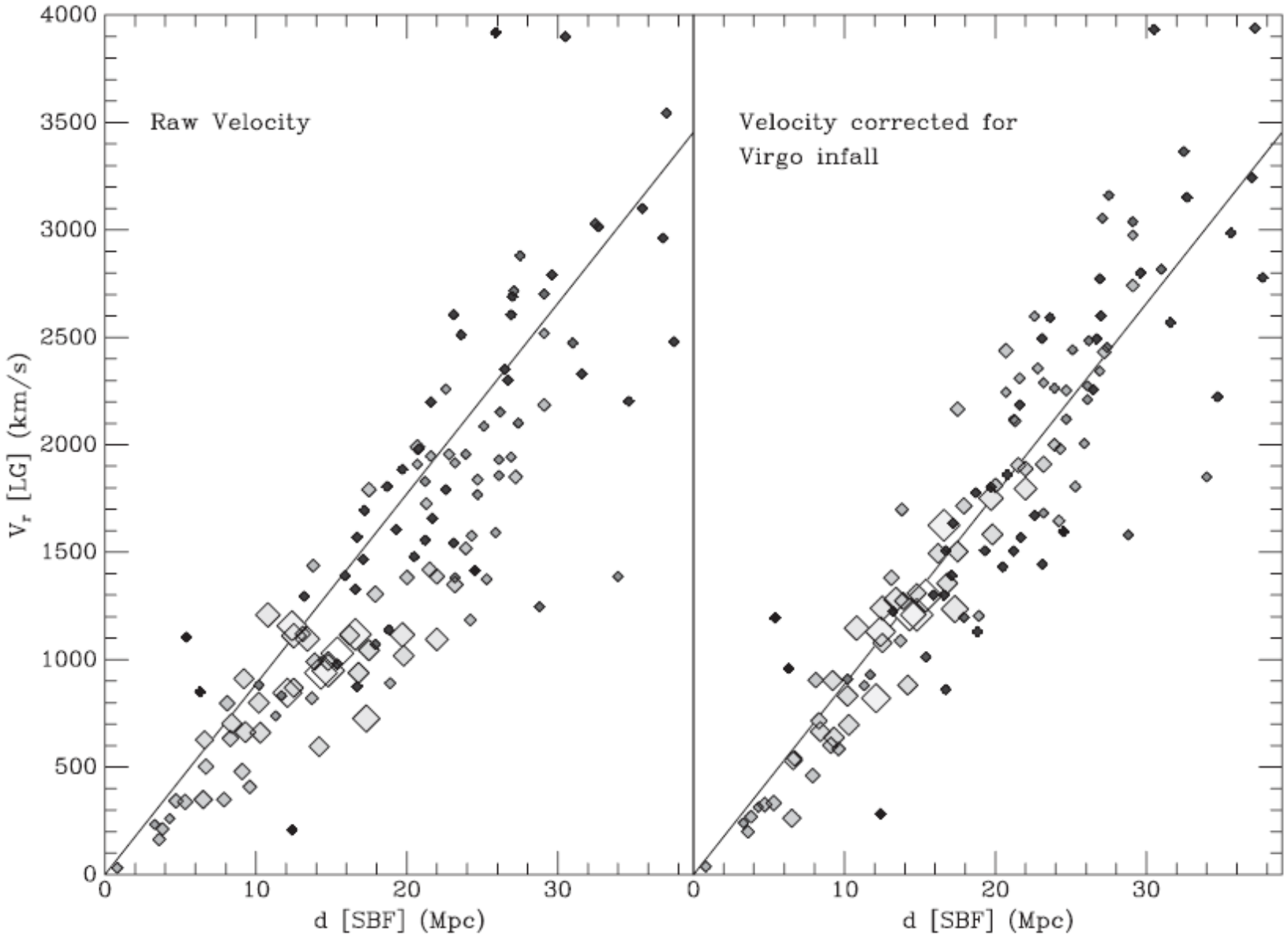
- What if the redshift isn't always due to cosmic expansion?
- Consider all types of velocity

$$V_r = H_0 d + V_P$$

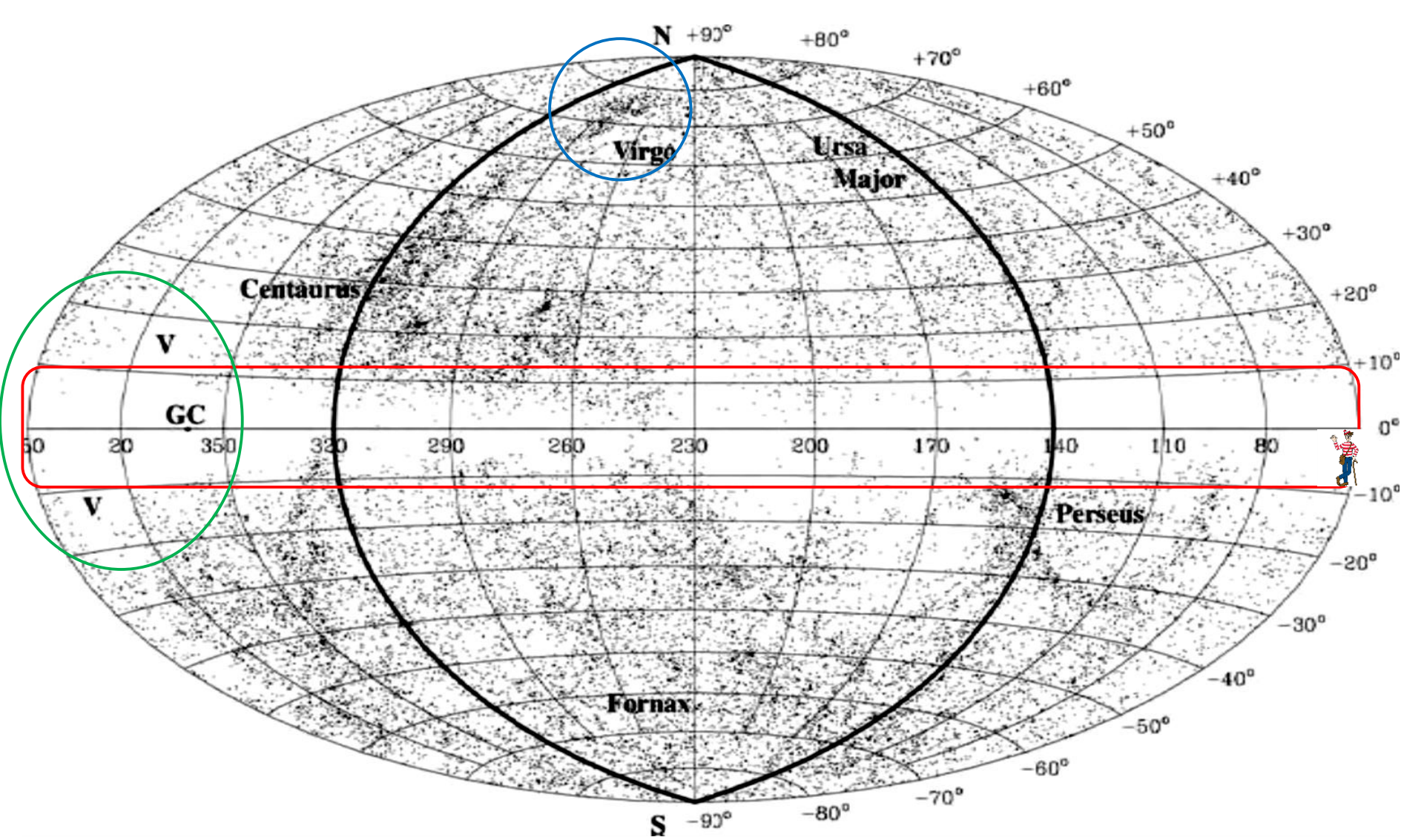
- V_P is **peculiar motion**
- Galaxies tend to move towards regions of high density → peculiar motion

VIRGOCENTRIC INFALL

- The local group is believed to be falling toward Virgo Supercluster
- Introduces bias on H_0 measurements made for these galaxies



Measured V_r for nearby galaxy groups, without/with corrections for Virgocentric Infall.
S+G, Fig. 8.15, p. 348



LEGEND

Zone of Avoidance

Virgo Cluster

Local Void

Supergalactic Plane

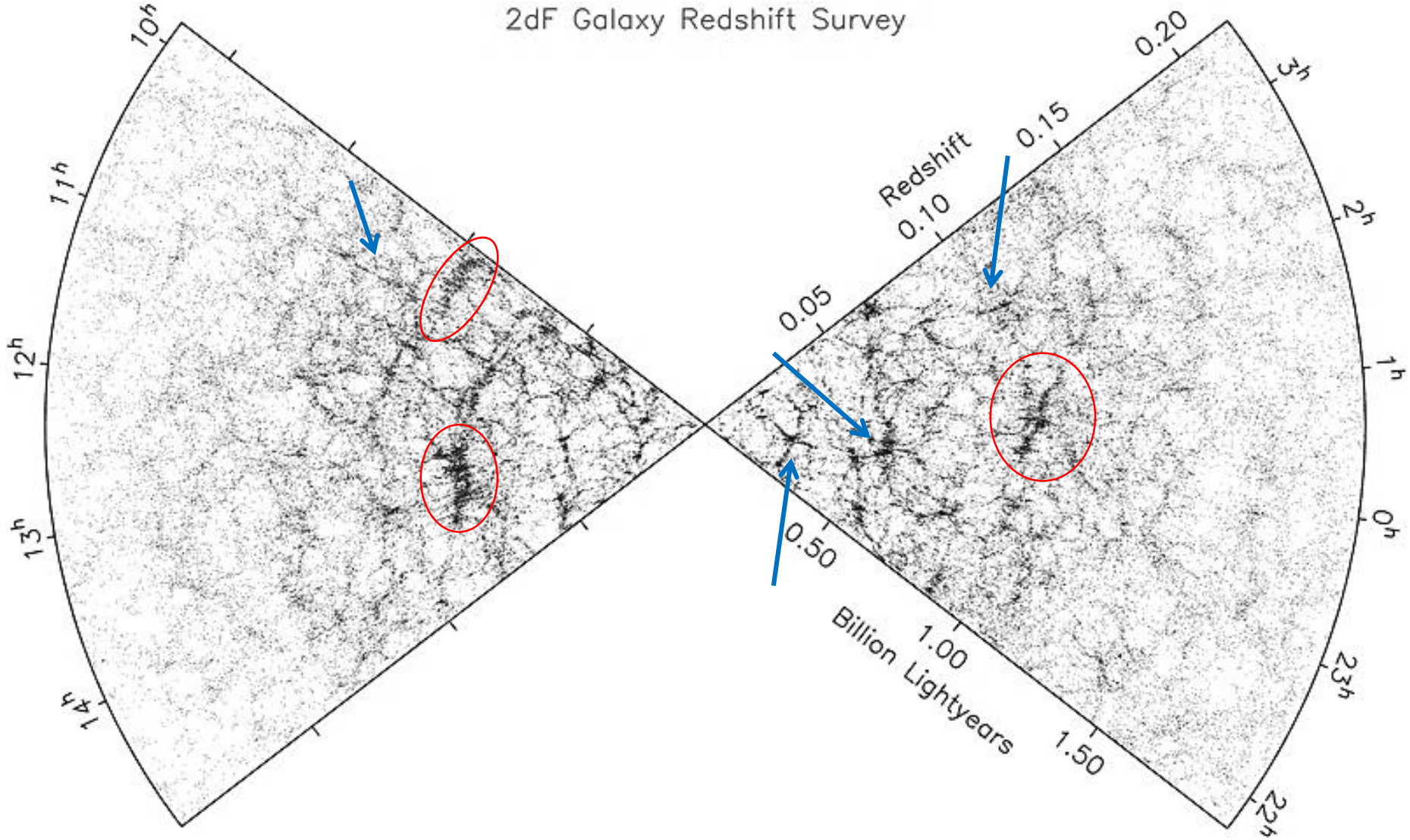
Galaxy distribution as seen from Earth.
S+G, Fig. 8.1, pp. 315-6

LARGE SCALE STRUCTURE

- Galaxies form structure in our sky
- Can make out many filaments and clusters in previous image
- Most galaxies appear to reside in ‘Supergalactic Plane’

2DF GALAXY REDSHIFT SURVEY

- AAO measured redshifts of 93170 galaxies
- Used Hubble Law to determine approximate distance



LEGEND

Walls

Dense Clusters

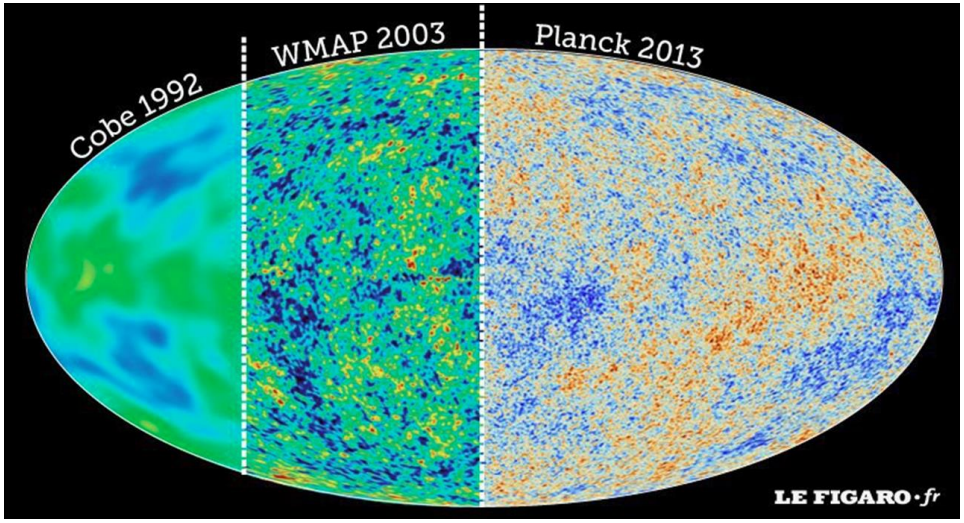
The 2dF survey (AAO) measured the redshifts of 93 170 galaxies and produced a distribution map.
S+G, Fig. 8.3, p. 319

2DF GALAXY REDSHIFT SURVEY

- Can see much structure, such wow 
- Malmquist bias kicks in as z increases…
- Peculiar motion causes walls to appear more dense, and causes clusters to appear elongated
- Universe appears to form a cosmic web
- What formed the web?

COSMIC MICROWAVE BACKGROUND

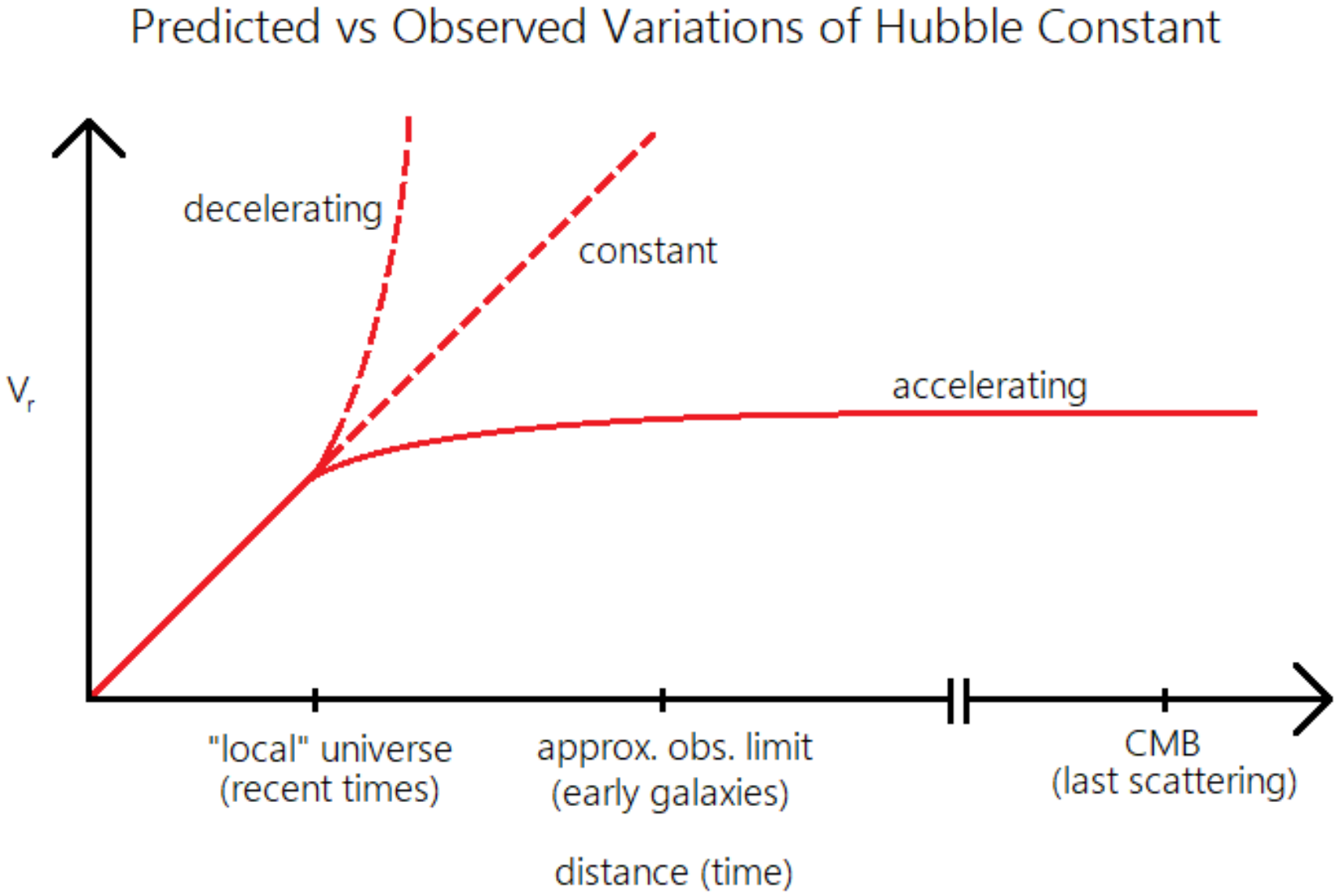
- CMB gives insight into density profile of early universe (before last scattering)
- Slight density fluctuations in CMB produce vast cosmic web in simulations
  - Dubinski & Gravitas
  - Millennium Simulation
  - Illustris (main page)



"Where is my Planck Beach Ball?" (Source)

LSS: IMPACT ON GALAXY EVOLUTION

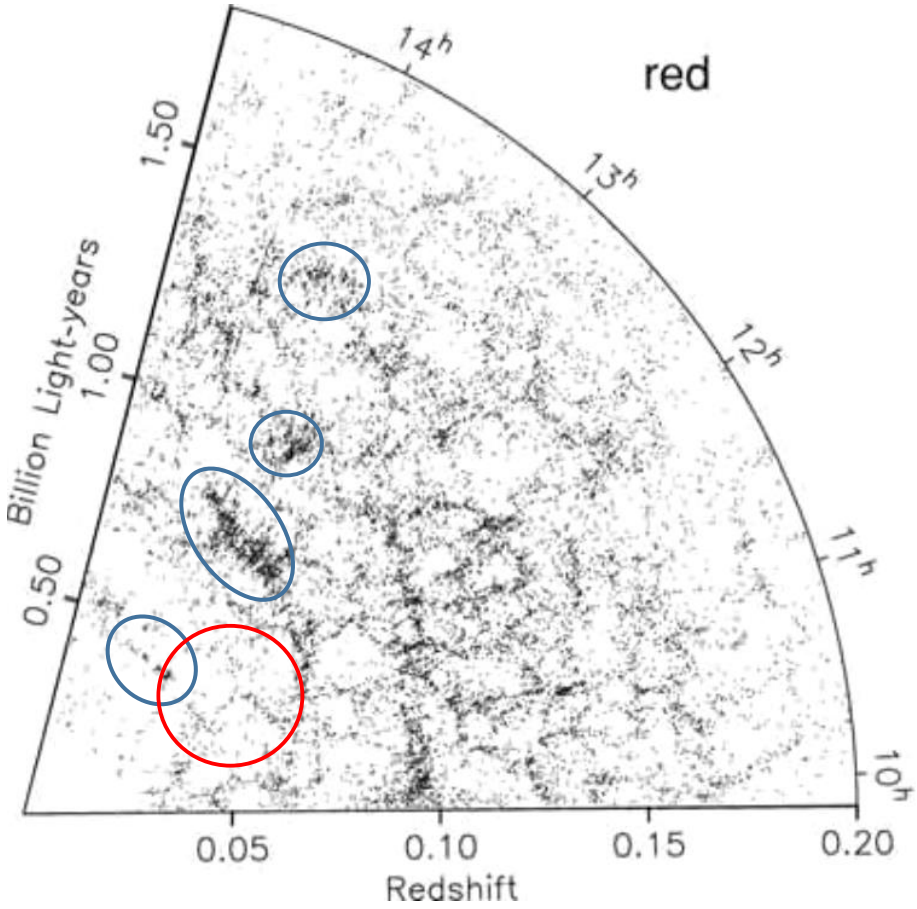
- Flow of material in LSS can influence galaxy evolution (recall Illustris)
- Can have major implications for end result of galaxy mergers
  - 2 spirals can sometimes form a dwarf spiral or a polar ring galaxy



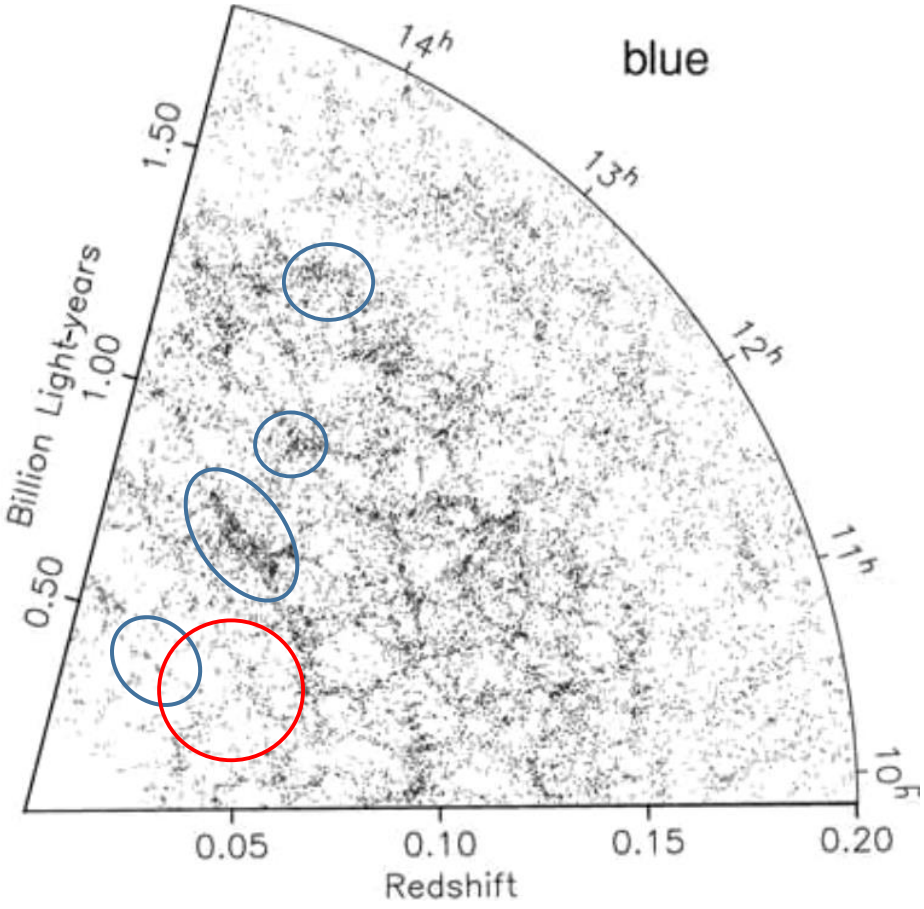
Beautiful plot describing the variation of H_0 as we look back in time. The slopes of each line describe the expansion of the universe. Dashed lines are possible expansion descriptions, and the solid line reflects actual observations.

Airey, 2017, MS Paint

MORPHOLOGY DISTRIBUTION



Elliptical, S0



Spirals, Irregulars

Clustering of different morphological types.
S+G, Fig. 8.5, p. 321

MORPHOLOGY DISTRIBUTION

- Tend to find ellipticals and S0 in regions of high density; spirals and irregulars are more evenly distributed
- Possibly because dense regions facilitate more mergers → more ellipticals

GALAXIES AS TEST PARTICLES

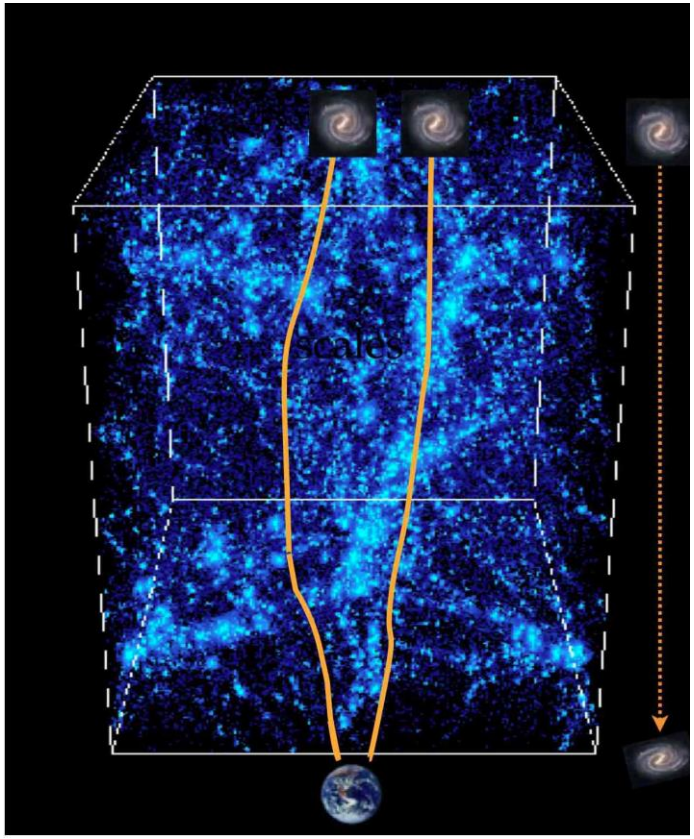
- Can use galaxies to test models of cosmology
  - Distribution of Dark Matter
  - Rate of acceleration of Universe

MICROLENSING

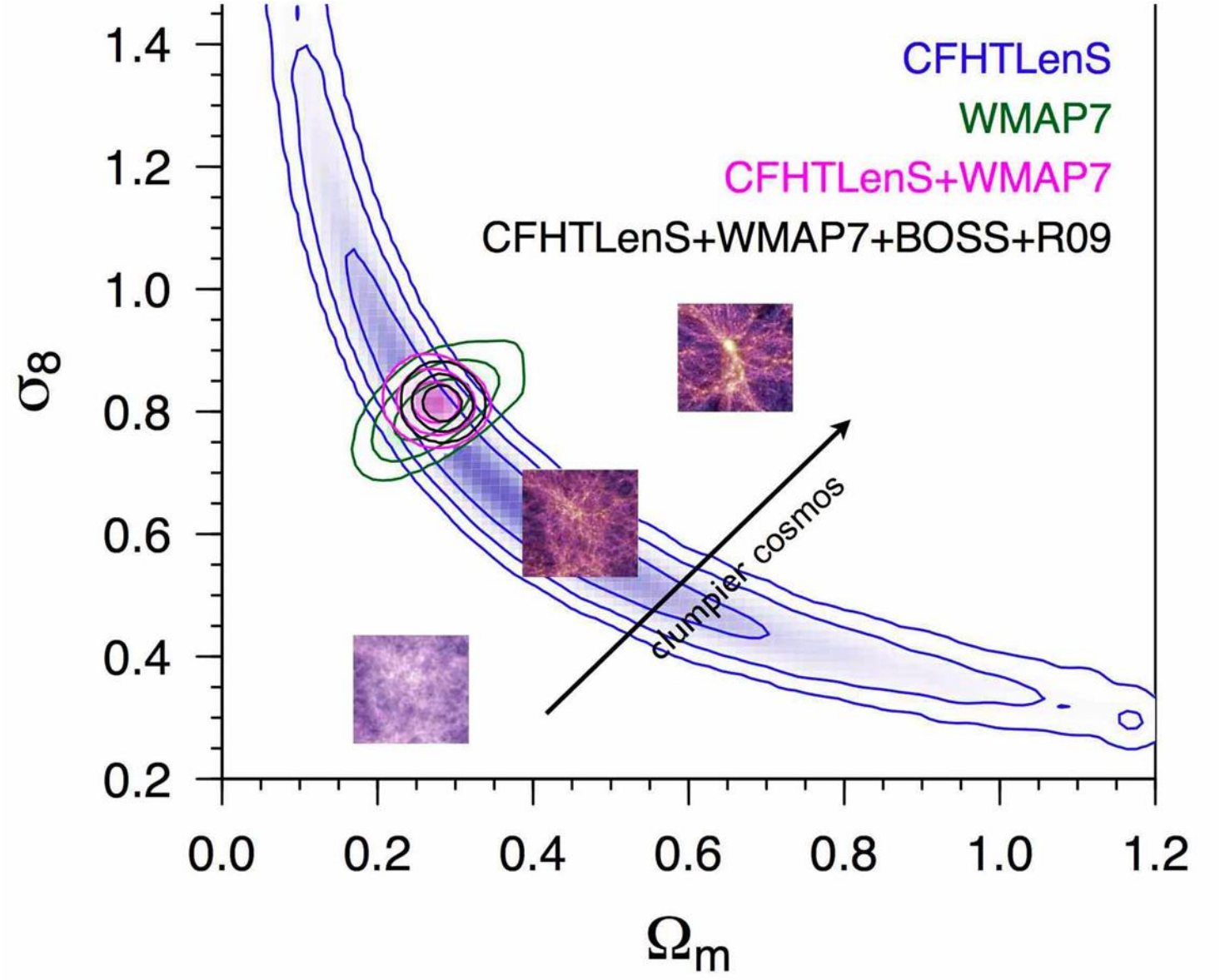
- Have all heard of gravitational lensing
- Weak Gravitational Lensing (WGL) allows measurements of the **power spectrum**
  - Difference between the local and mean universal density
- WGL lets us map density distributions of LSS
  - A useful method for determining DM distributions
- In near future, high z observations will let us map DM distribution wrt t

COSMIC SHEAR

- WGL specifically due to LSS
- A ‘refraction’ of light through regions of varying density
- Acts as a measurement of the density of matter Ω_m between us and the viewing point



Distortion of light in clumpy universe
Kilbinger, 2015



Matter density vs ‘clumpiness’ as expected by various surveys
Kilbinger, 2015, p. 26

DARK ENERGY

- Can also use galaxies to test dark energy models
- Recall Hubble law:

$$V_r = H_0 d$$

- Eq. assumes H_0 is independent of time (or redshift)
- High-redshift observations show this is not true
- Universe appears to be accelerating

DARK ENERGY

- Can make H_0 measurements at various redshifts and find acceleration to determine dark energy (Λ) abundance
- What if Λ is also time-dependant?
  - Called Quintessence
  - Represent DE as a scalar field, not a constant
  - Quintessence becomes a fundamental force (like Gravity)
- Alternatively, may not even need DE to explain expansion of universe…

IN OTHER NEWS…

- Researchers speculate that the expansion of the universe may be due only to the LSS
- Models of gravitational interactions between the LSS of the Universe were able to reproduce the expansion
- Could be good
- Link here if anyone is interested in giving it a read…