The Local Universe

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2010 Undergraduate ALFALFA Workshop

(with thanks to Brian Kent!)

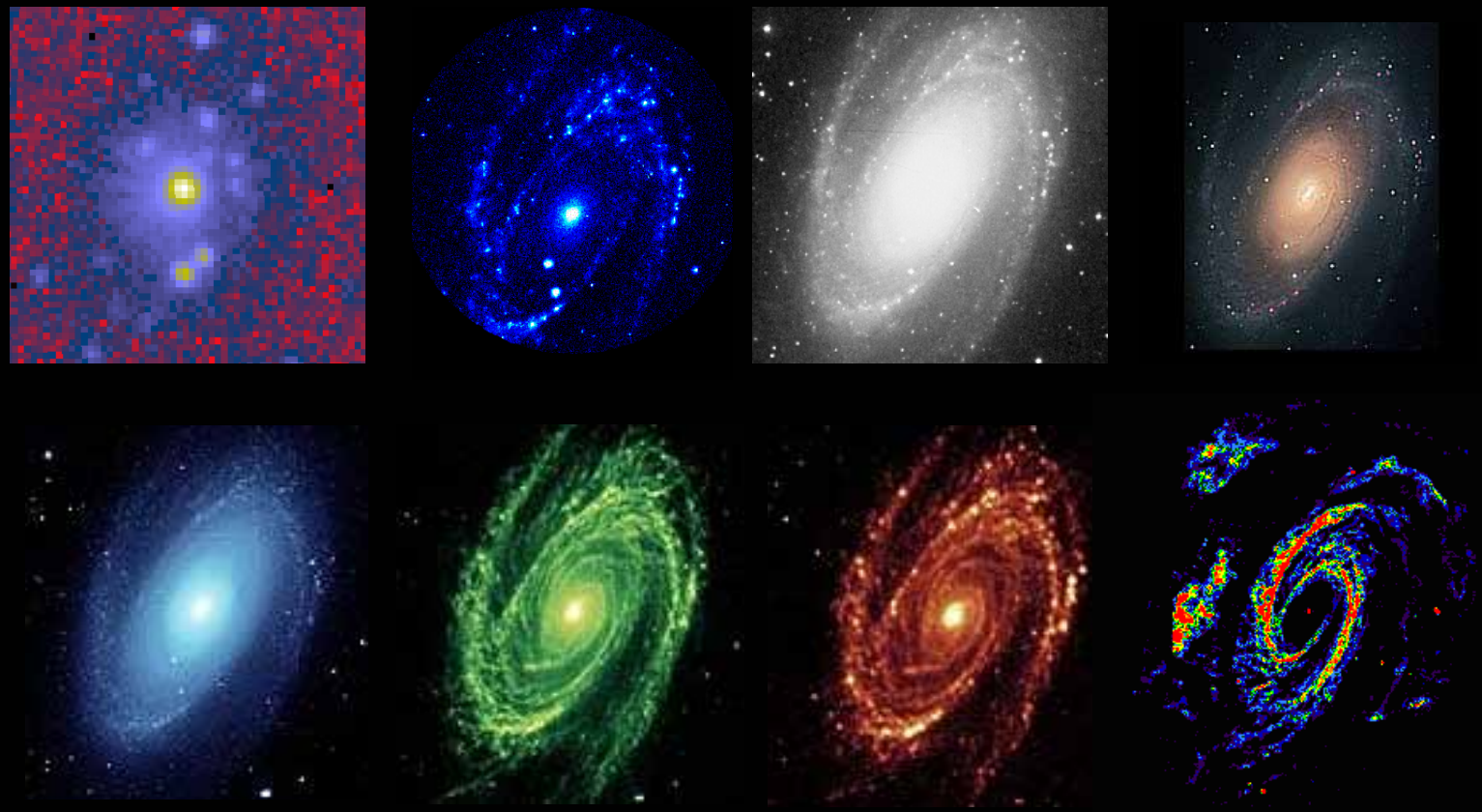
What is a Galaxy?

- The Wikipedia Definition: “A **galaxy** is a massive, gravitationally bound system consisting of stars, an interstellar medium of gas and dust, and dark matter.”

M31, from Hubble

What do Galaxies Look Like?

- M81: X-Ray, UV, Visible, Visible, NIR, MIR, FIR, Radio



From the IPAC Multiwavelength Museum

Types of Galaxies

- From dwarfs to giants, from spirals to ellipticals

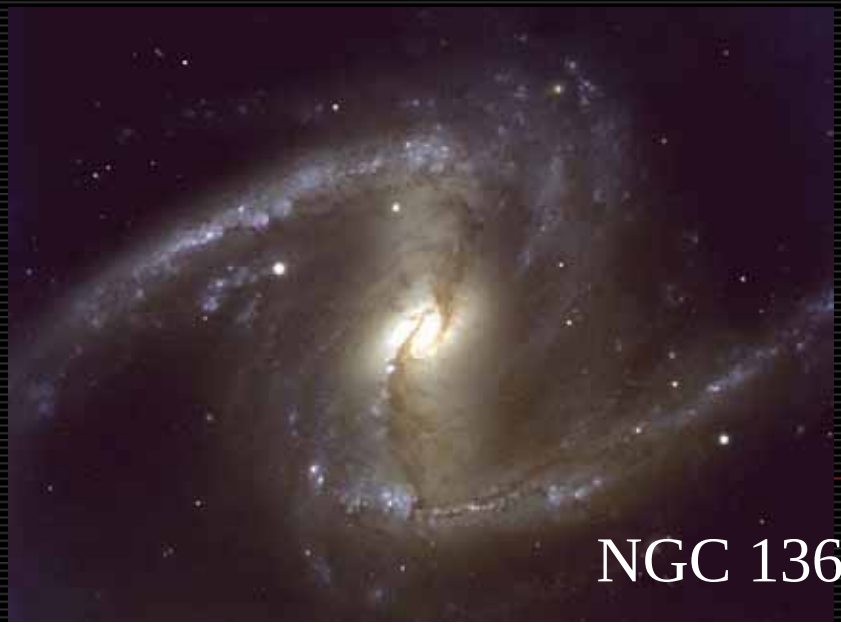
Andromeda, a spiral galaxy, with a nearby dwarf elliptical

M31, from Hubble

Types of Galaxies: Spirals

- Thin disks
- Most have some form of a bar – arms will emanate from the ends of the bars
- Other classification:
  - Relative importance of central luminous bulge and disk in overall light from the galaxy
  - The tightness of the winding of the spiral arms
  - Barred or not?

M51

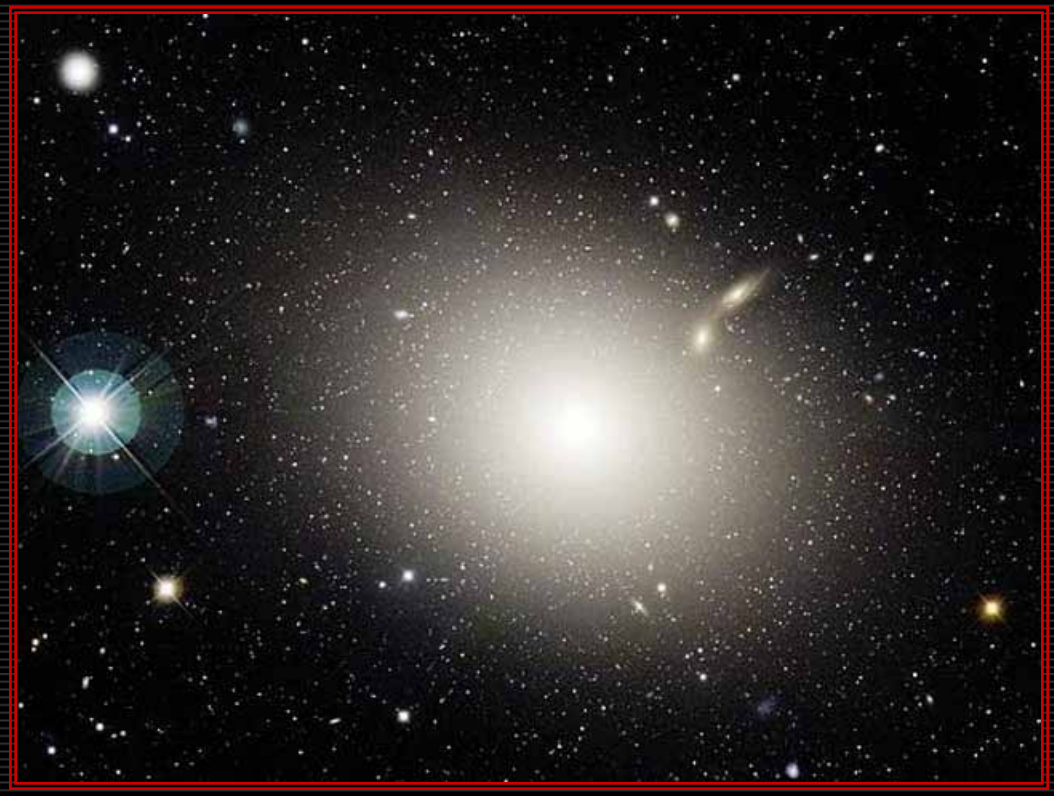


NGC 1365

M33

Types of Galaxies: Ellipticals

- Ellipticals: look like smooth, featureless "blobs"
- Older (redder) stellar populations
- Tend to have little neutral gas (HI) – so ALFALFA doesn't see these!
- More rare in the early Universe



M87 in the Virgo Cluster

Types of Galaxies: Irregulars

- Irregulars: Many different properties, often because of interactions or other unusual events nearby.

NGC 1427A

HST Image of Sagittarius Dwarf Irregular Galaxy (SagDIG)

Types of Galaxies: Irregulars

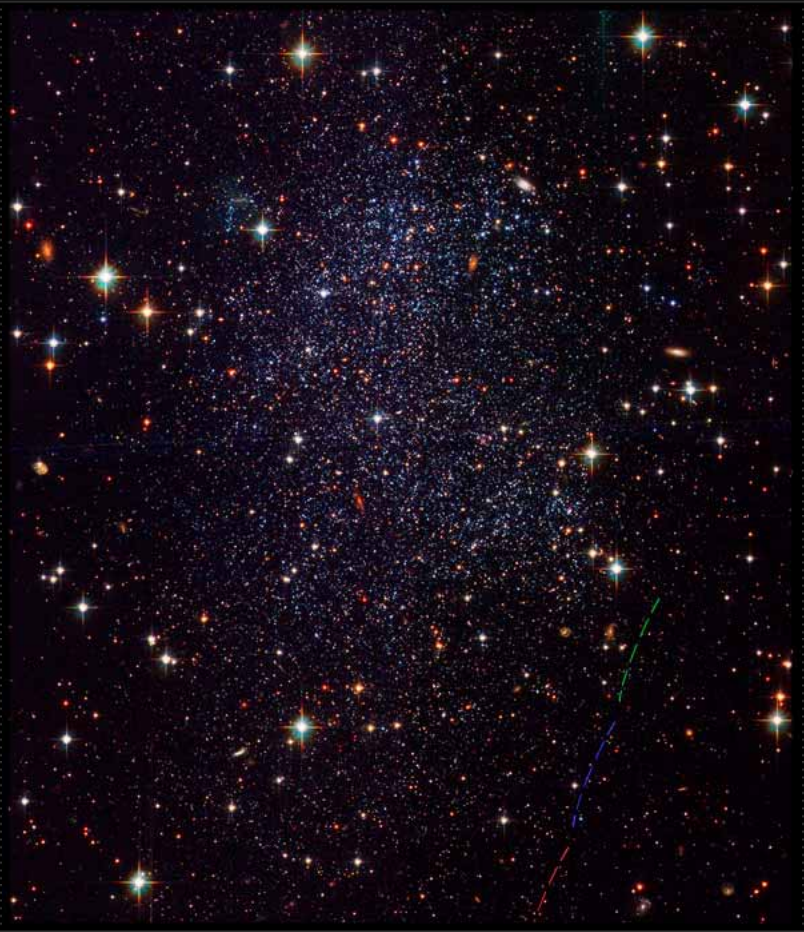
- LMC and SMC are satellite galaxies of our own – disrupted by gravitational interaction with the Milky Way

LMC and SMC

Dwarf Galaxies

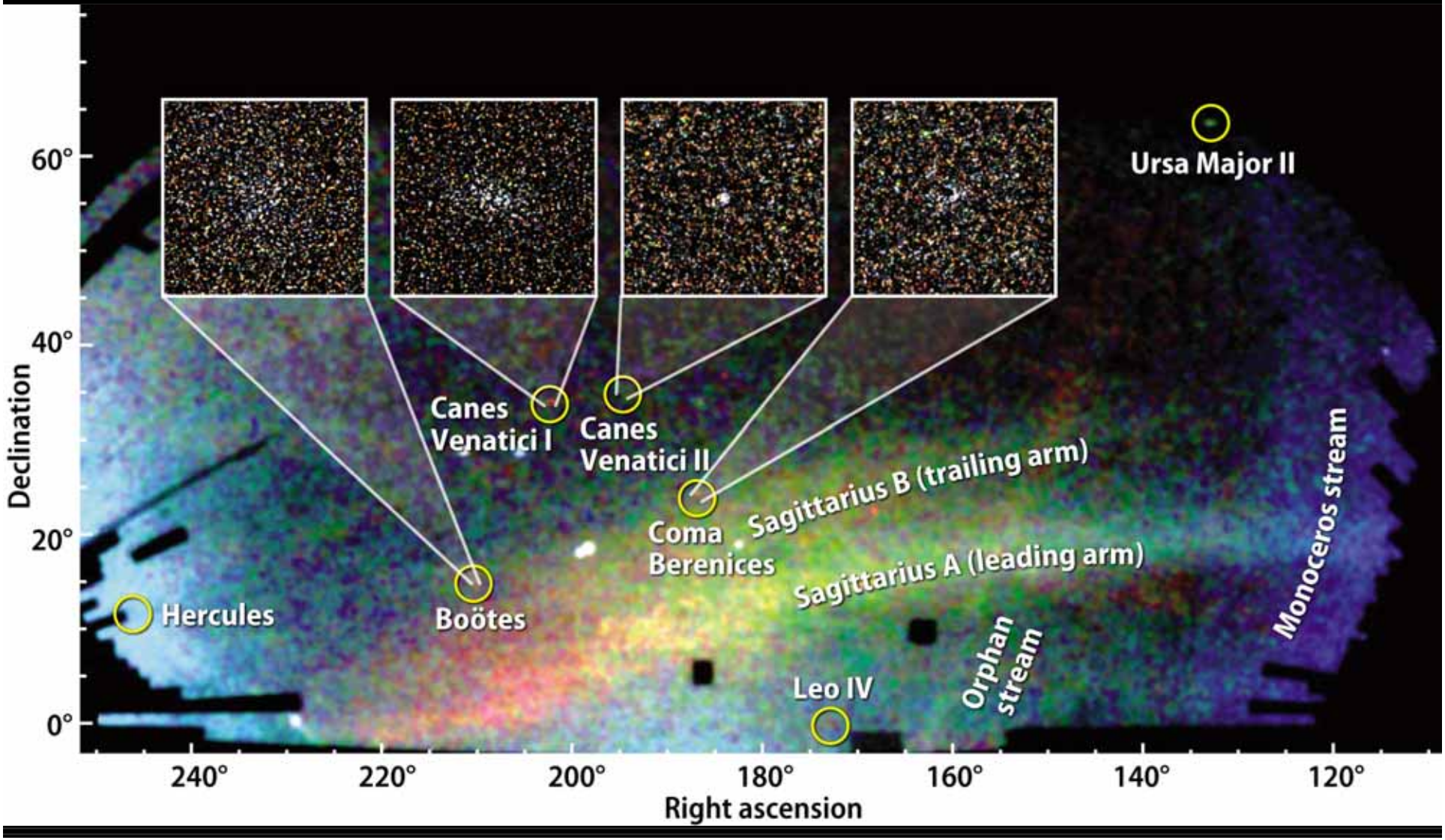
- Smaller size than giant galaxies
- Lower surface brightness
- Most common galaxies!

M32

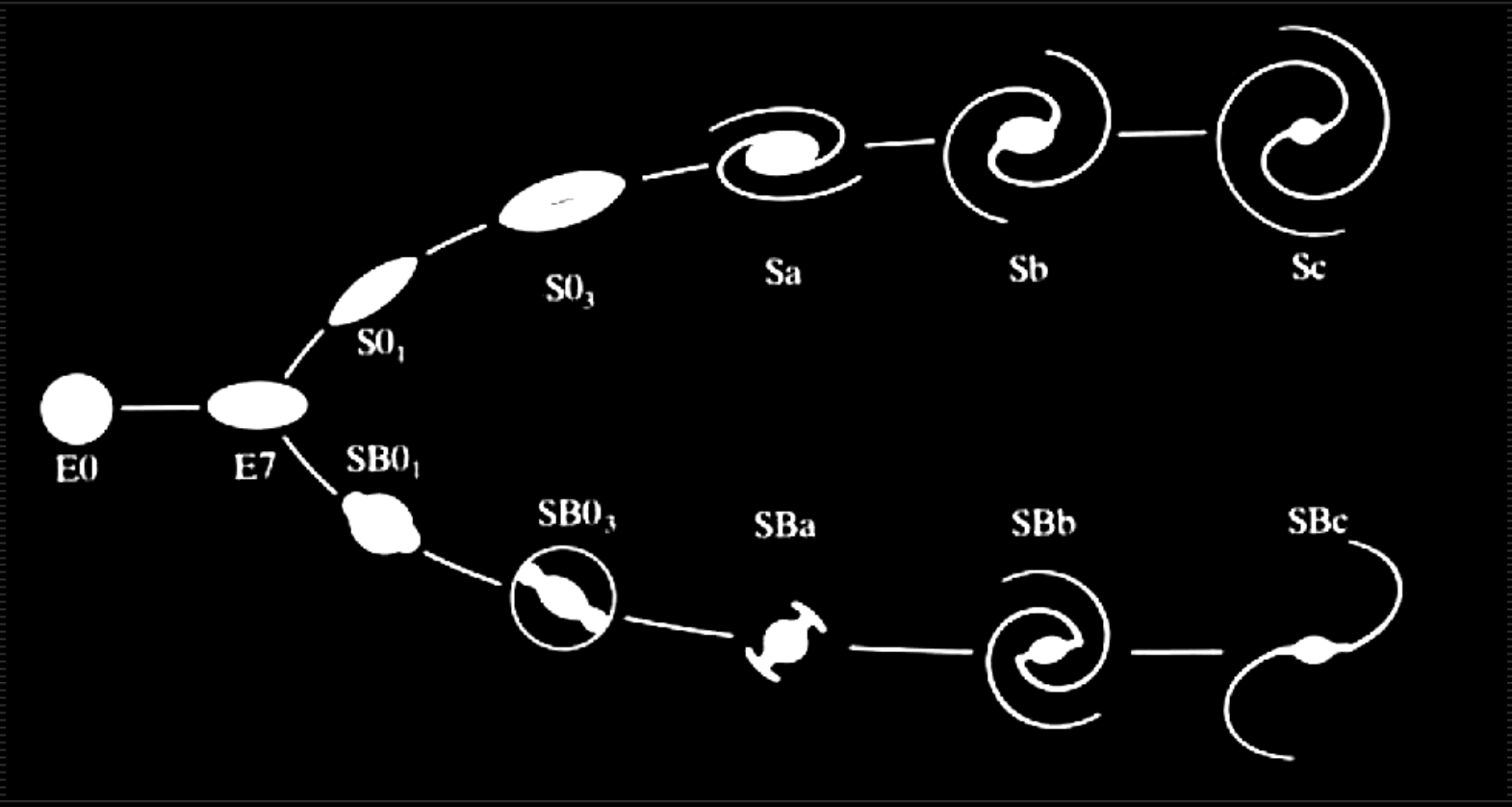


Sagittarius Dwarf

Dwarf Galaxies: SDSS Ultra-Faint Galaxies



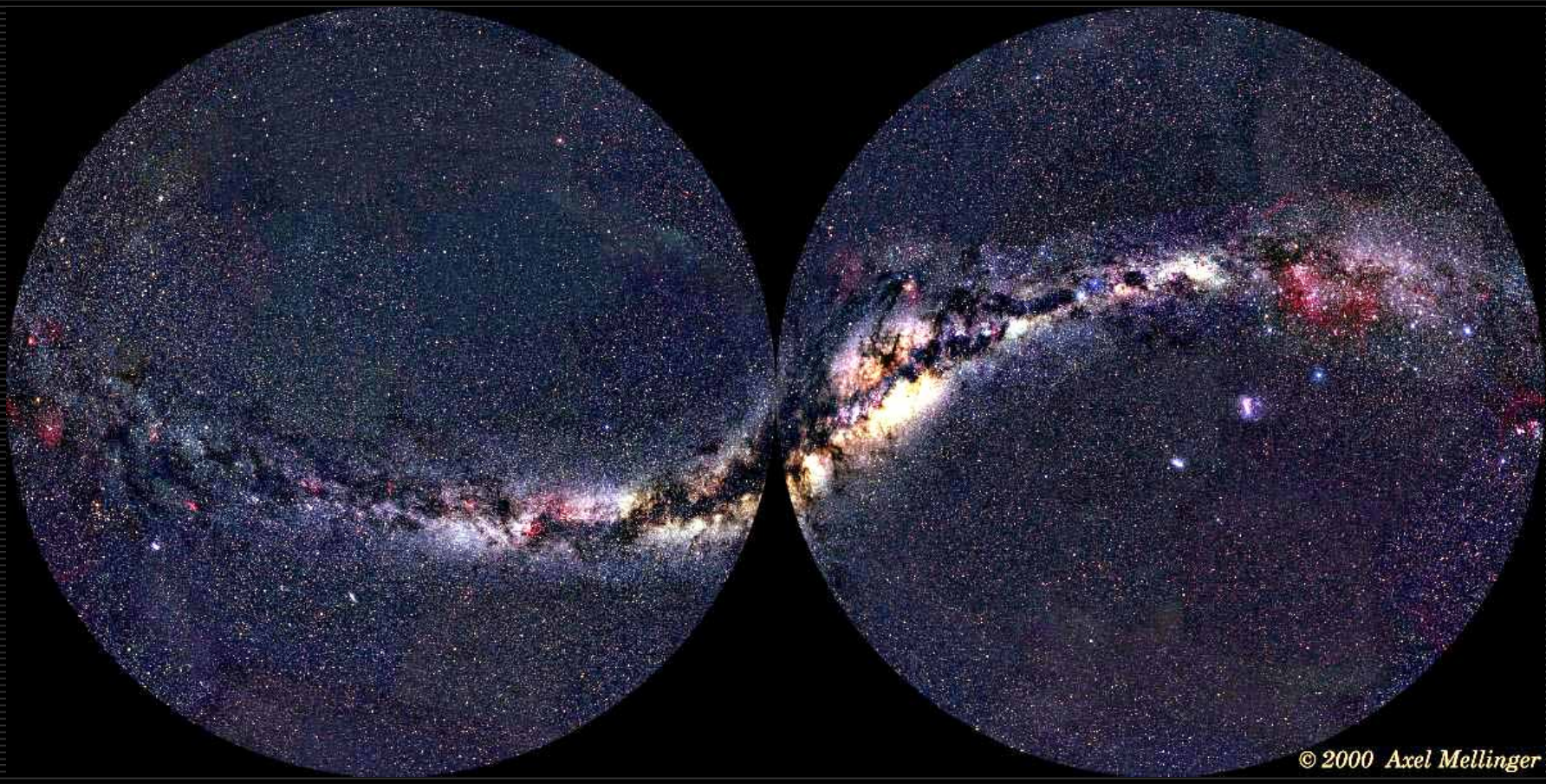
The Hubble Tuning Fork



Early Type **Late Type**

Our Galaxy: The Milky Way

- An Sbc galaxy that is 30 kpc in diameter



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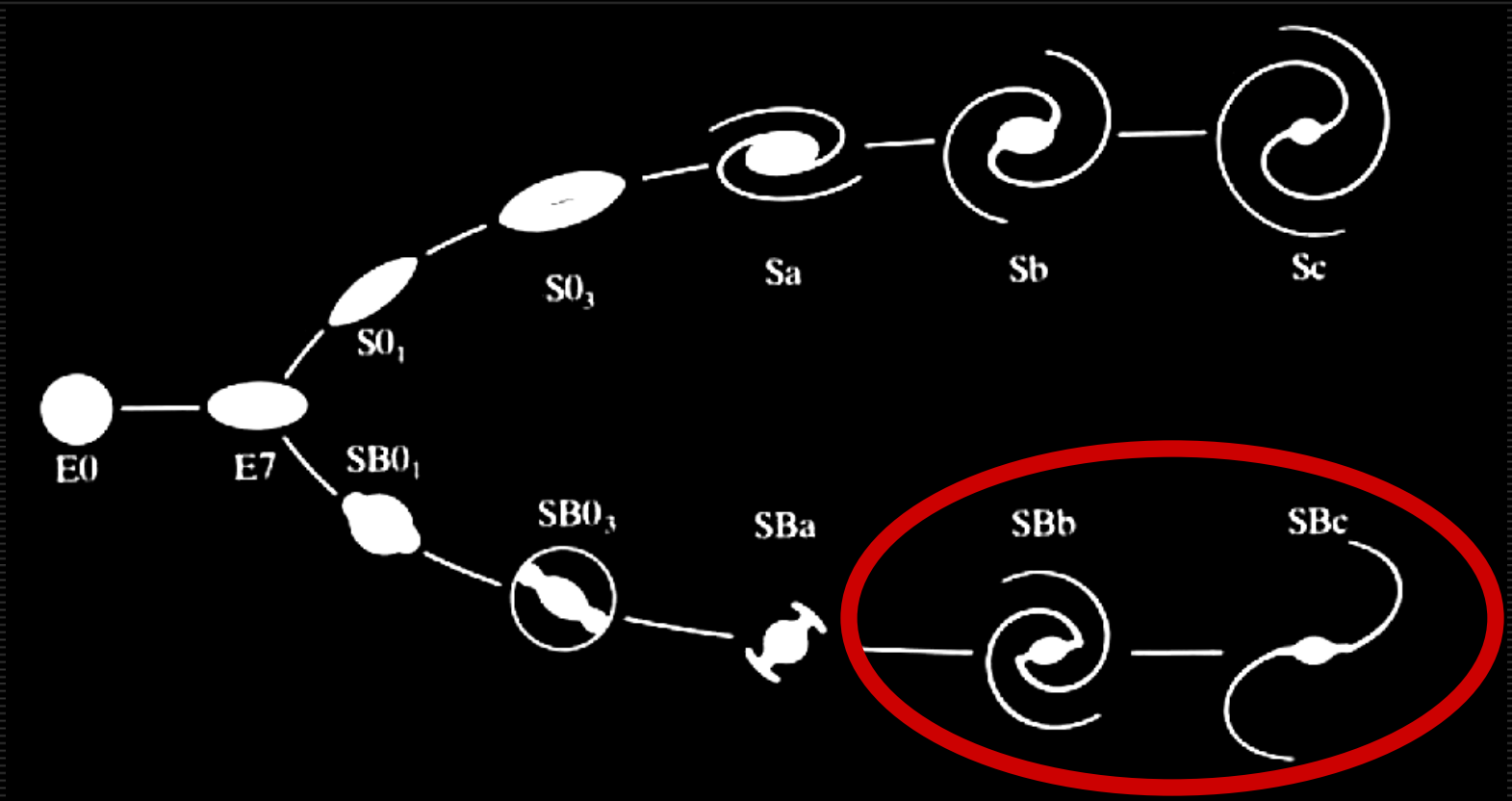
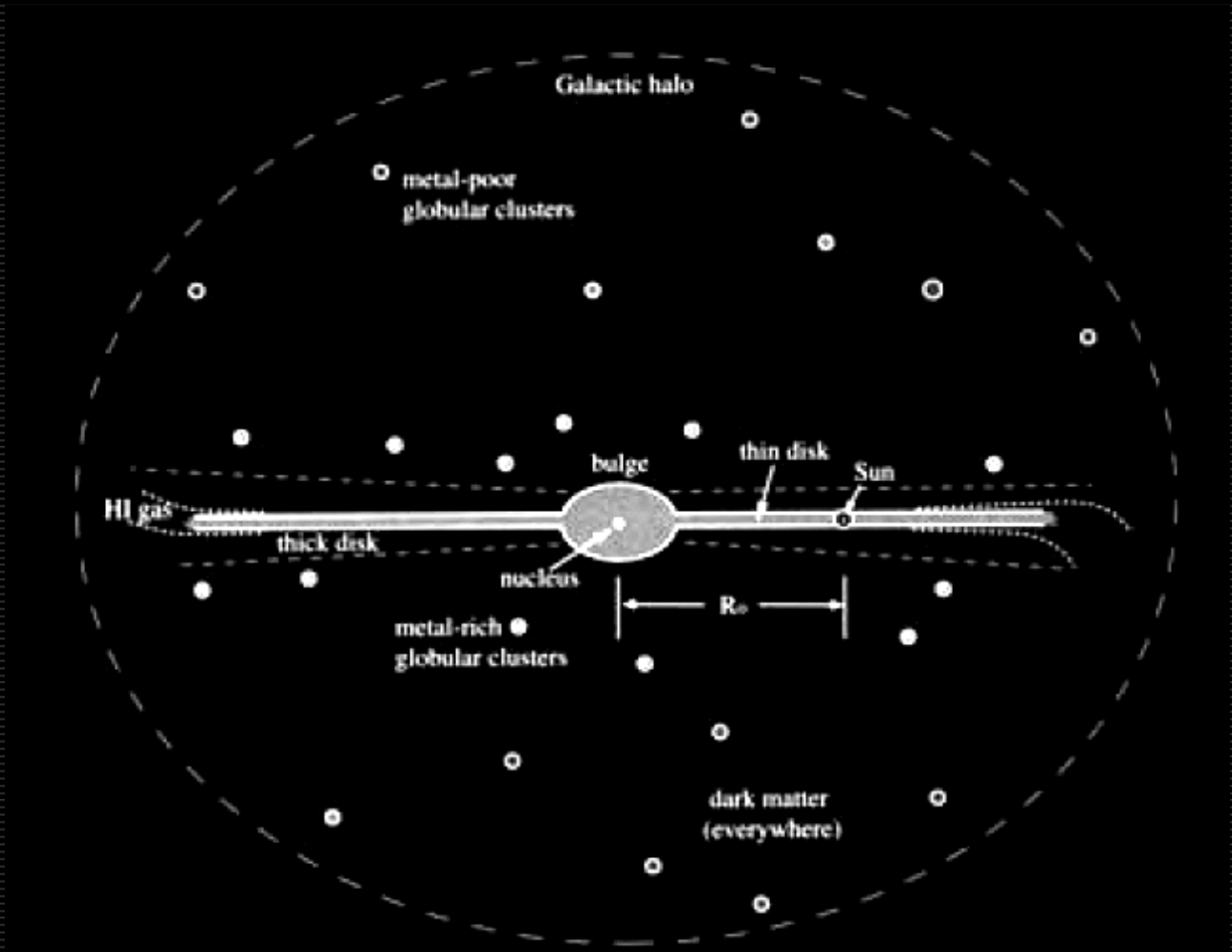


Early Type **Late Type**

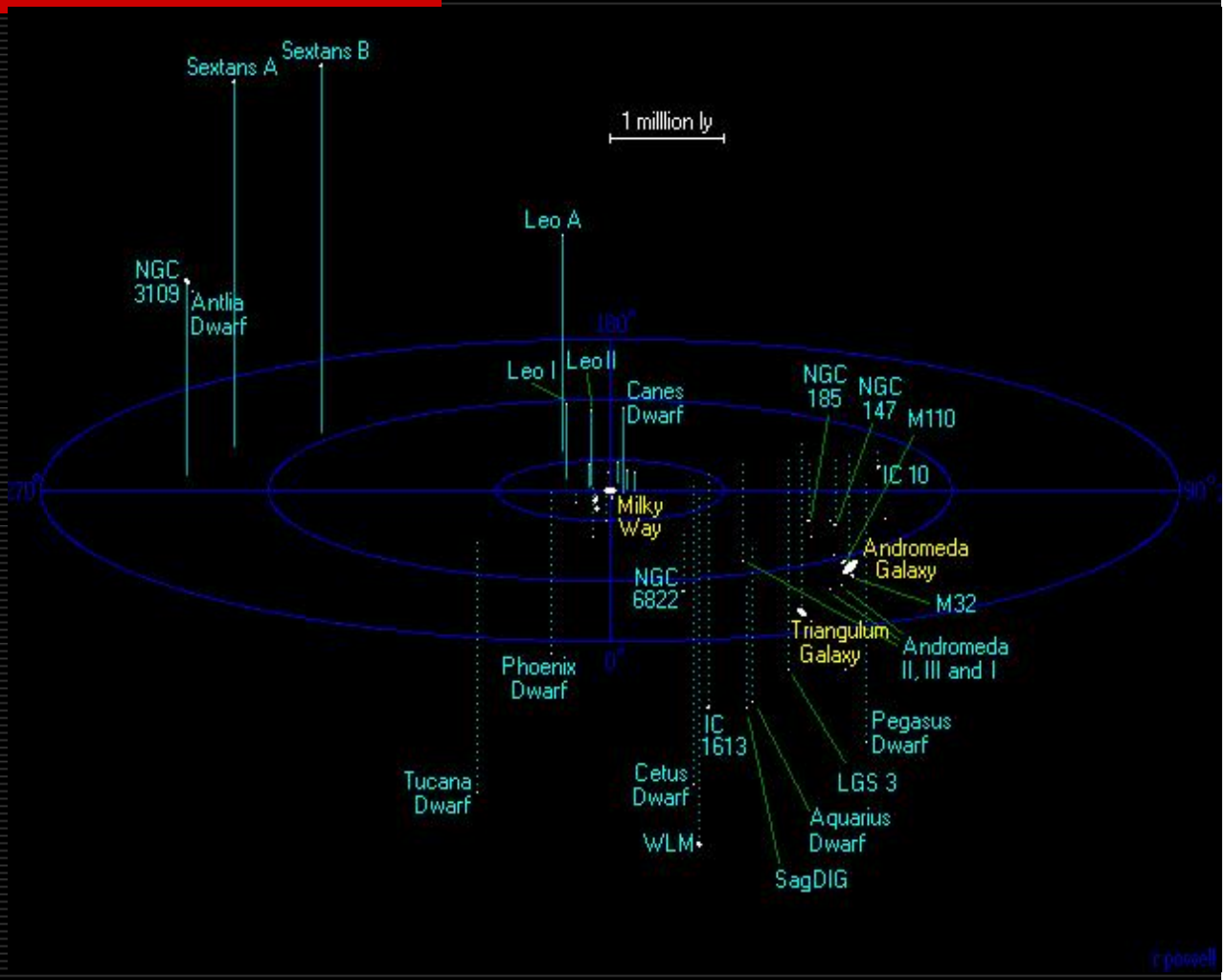
Anatomy of the Milky Way

- R_0 ~ 8 kpc
- 200 billion stars
- M_{tot} 5 x 10^{11} $M_\odot$
- SFR ~ 3 $M_\odot$/yr
- Bulge ~ 3 kpc in diameter



Our Neighborhood: The Local Group

- The Local group has 43 + 5? members (and growing), ranging from large spiral galaxies to small dwarf irregulars. Most galaxies are dwarf spheroidals...



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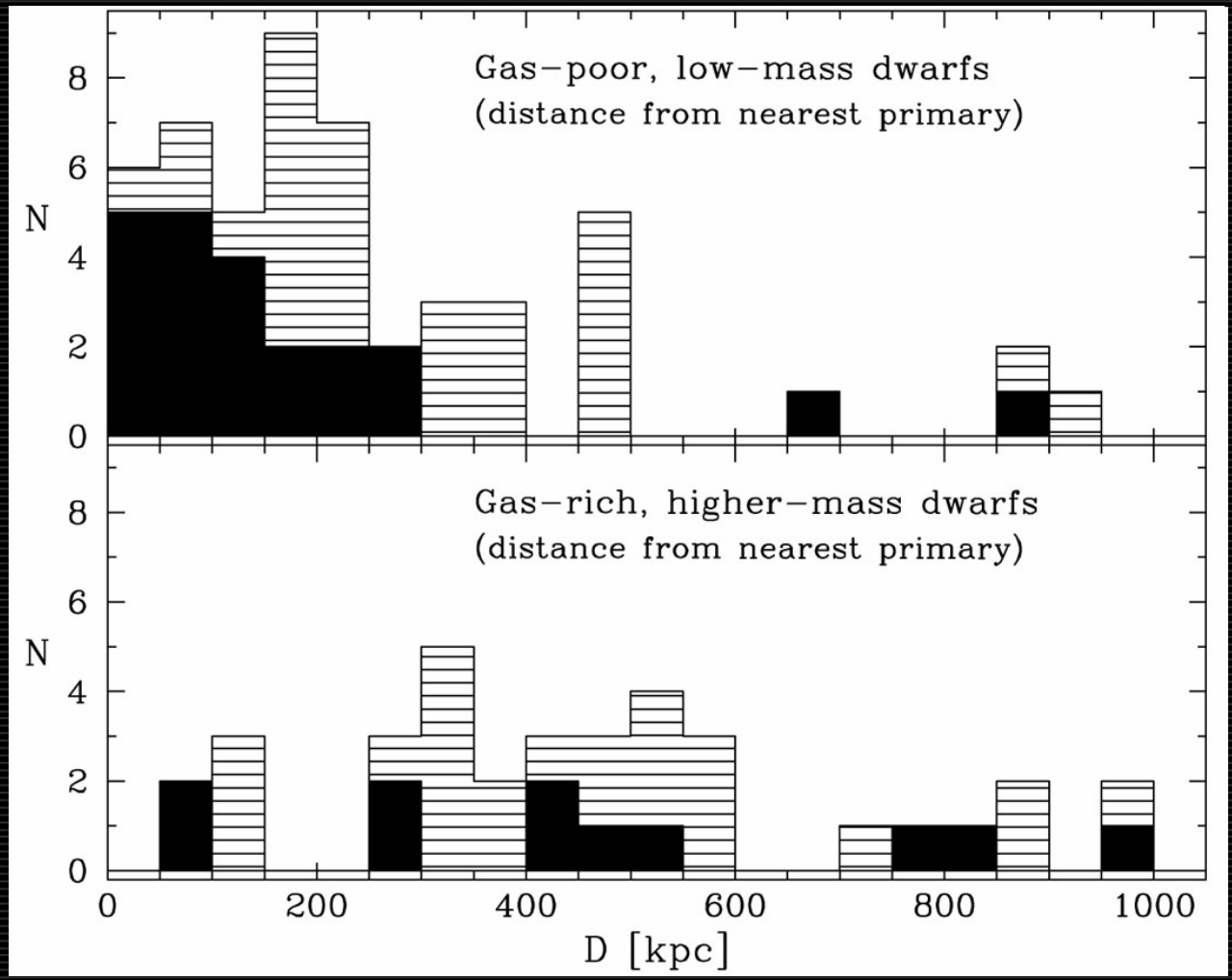


The Andromeda Galaxy

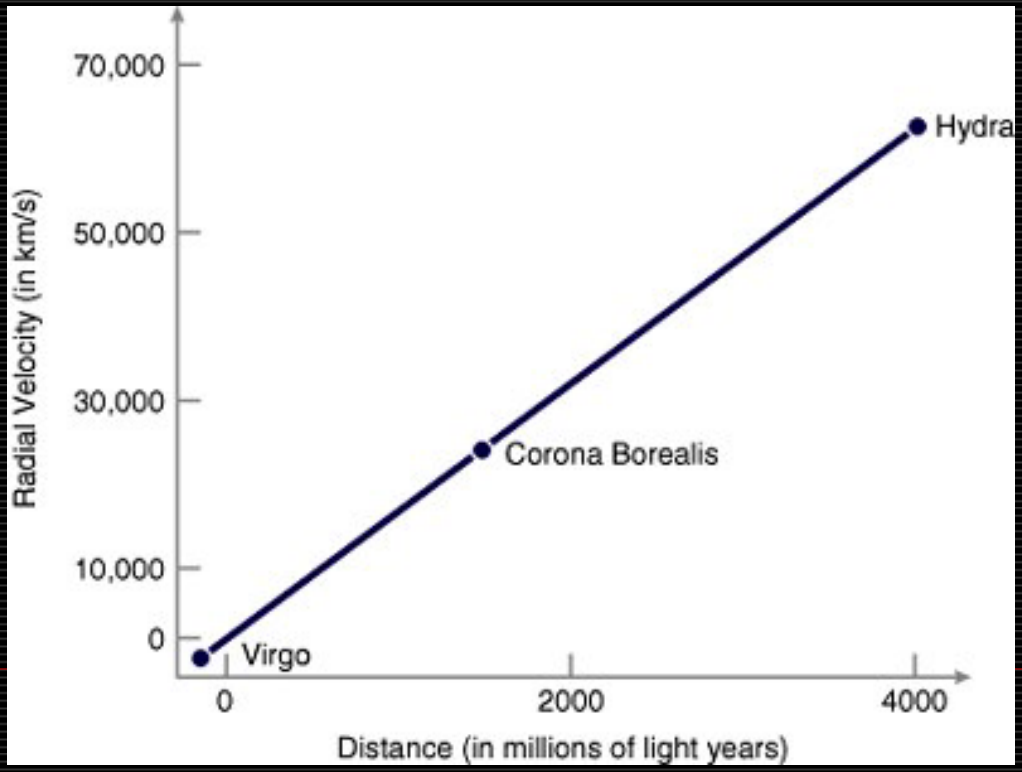
- Sb galaxy 770 kpc from the Milky Way.
- Larger, more luminous, with a larger disk scale length than the Milky Way – it even rotates faster at 260 km/s!
- At least 9 known satellite galaxies – dwarf elliptical and spheroidals!

cz = -300 km/s

Another Contribution from Hubble . . .

- The Universe is expanding!

$$cz = H_0 d$$



A simple calculation: Redshift

$$z = \frac{\lambda_{obs} - \lambda_0}{\lambda_0} = \frac{f_0 - f_{obs}}{f_{obs}}$$

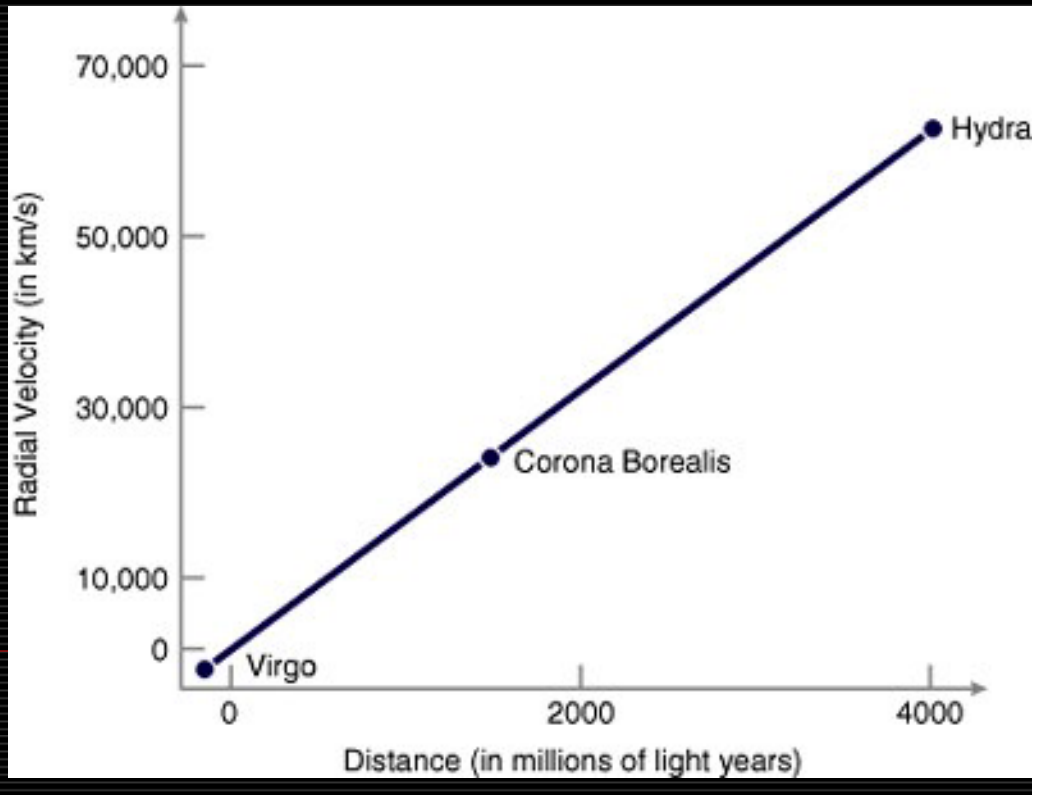
- Measure the shift in a spectral line – f_0 is the rest frequency
  (λ_0 the rest wavelength)
- Extragalactic objects often identified by their *cz* measurement.
- ALFALFA covers *cz* = –2000 to 17000 km/s (out to ~ 250 Mpc)

Another Contribution from Hubble . . .

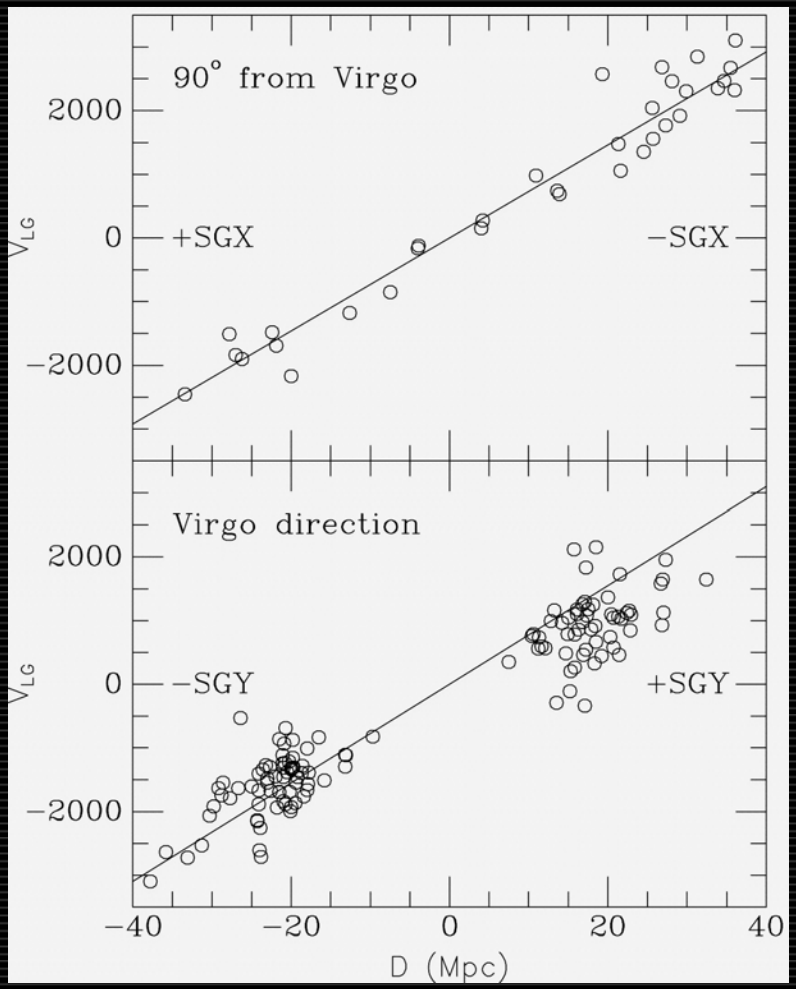
- The Universe is expanding!

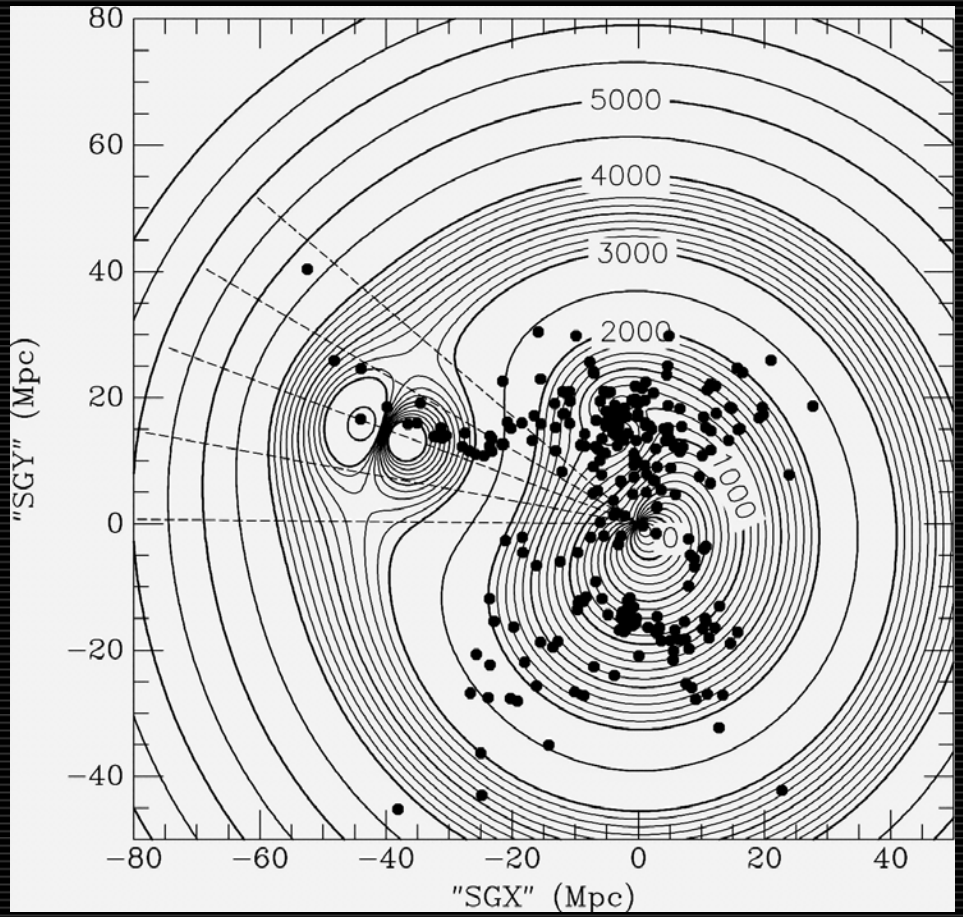
$$cz = H_0 d$$

- However, there are other factors to take into account in the local Universe – peculiar velocities! Deviations can be quite large depending on the galaxy, and whether it is part of a group or a field galaxy.



Distances to nearby galaxies

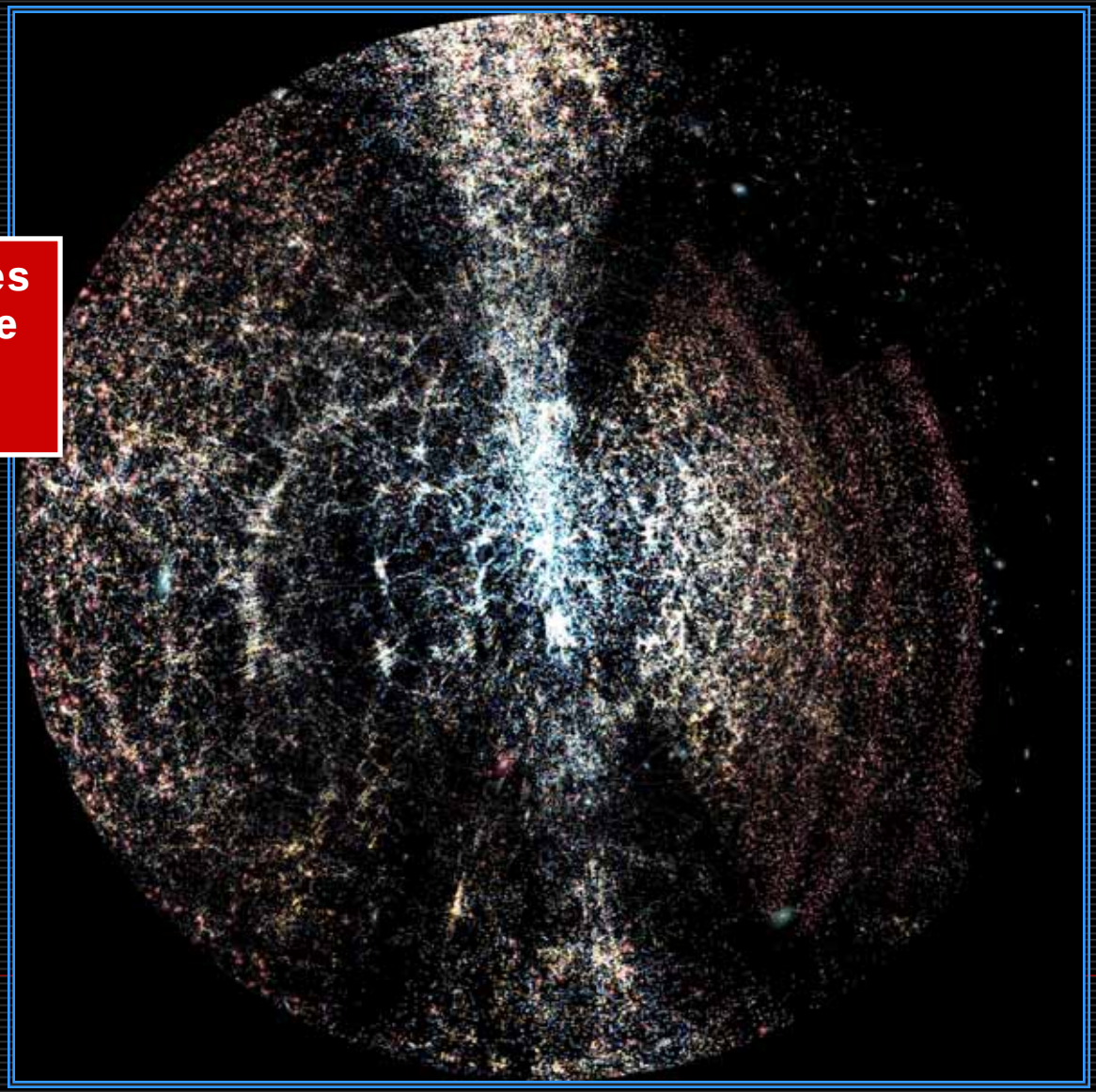




Tonry, et al. 2000

Distribution of Galaxies

~450,000 galaxies (SDSS, with more than 800,000 today!)



Distribution of Galaxies

- Structures in the Universe: The best place to find a galaxy is next to another one!
  - Groups
  - Clusters
  - Superclusters
  - Filaments and Voids

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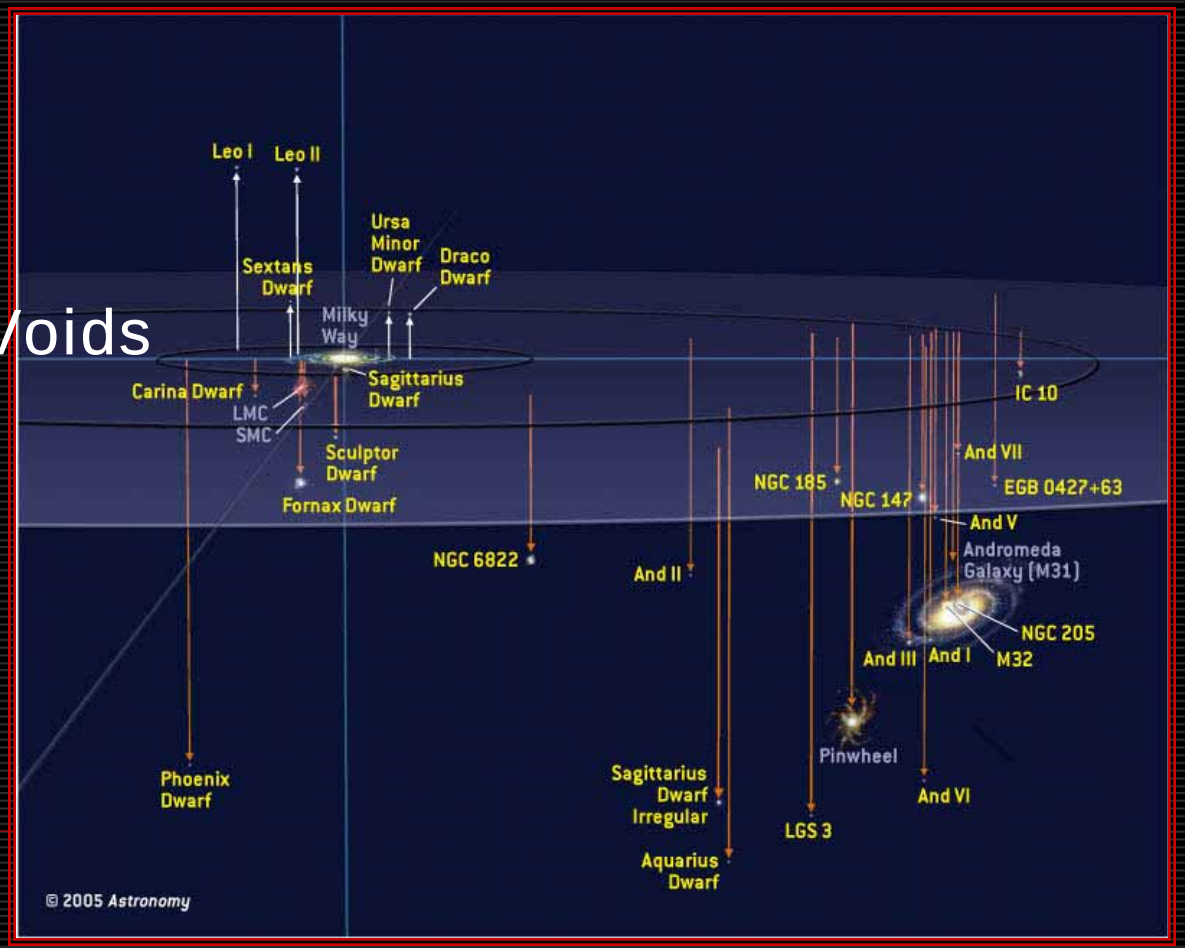
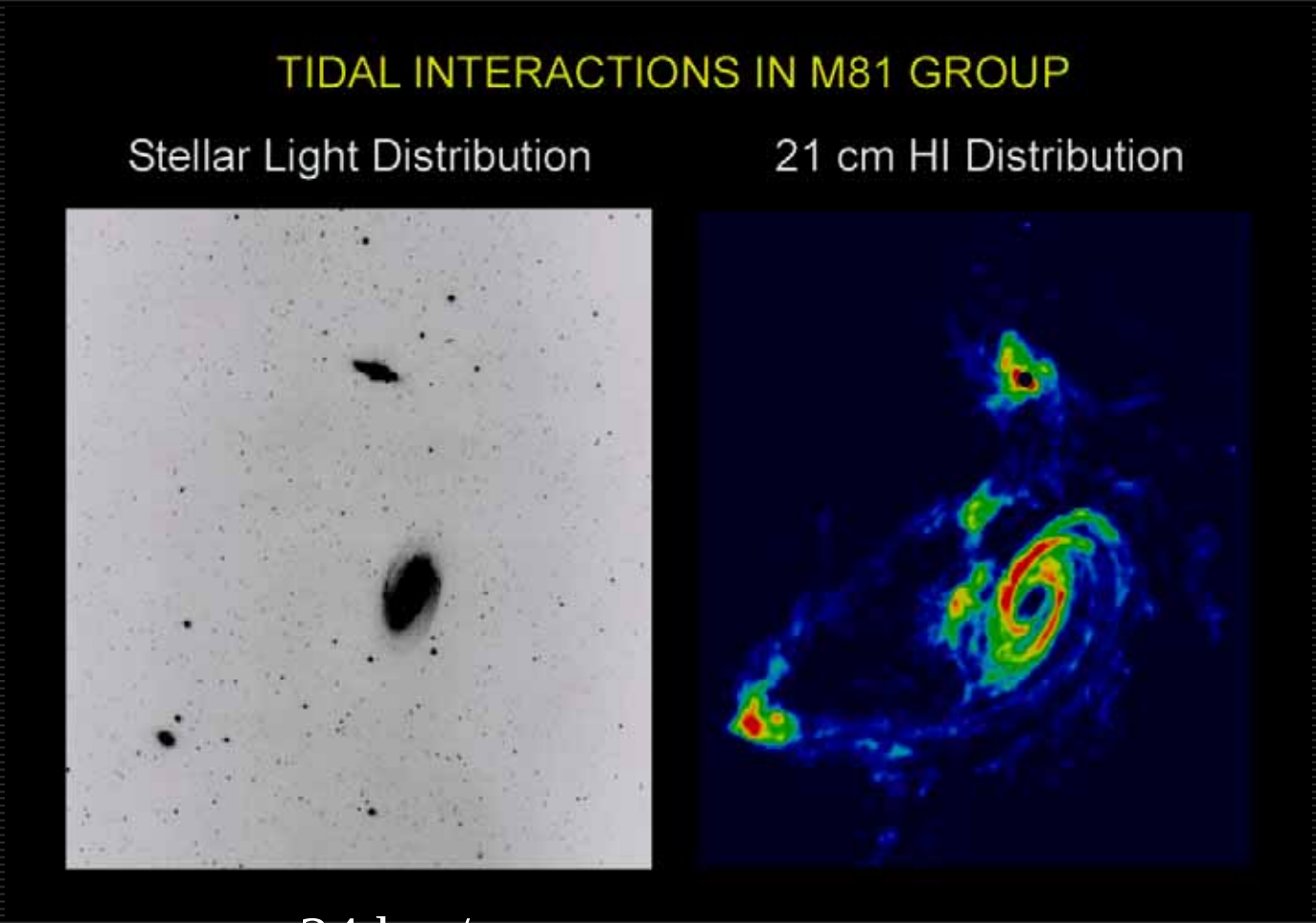


Groups of galaxies

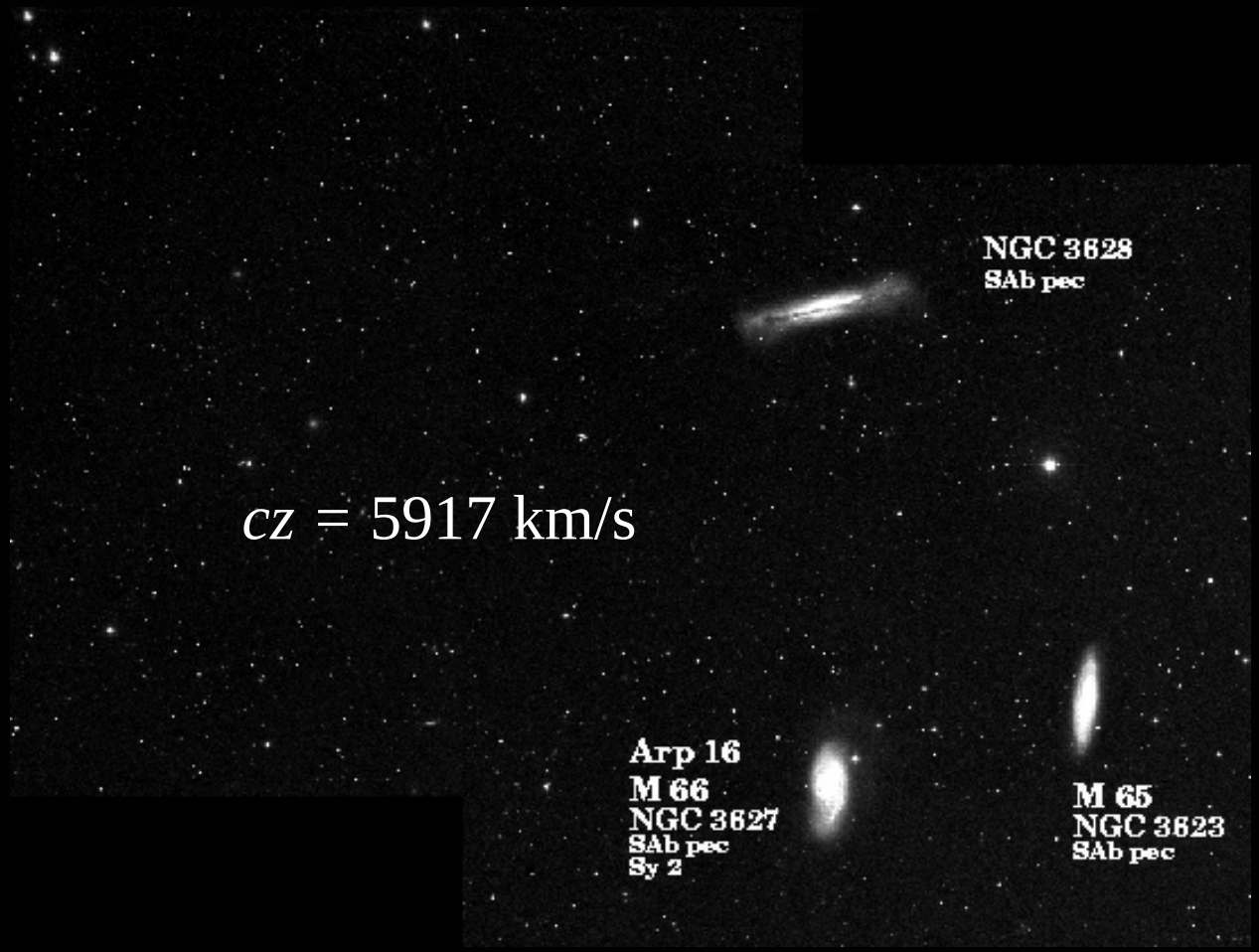
- Galaxies can be gravitationally bound to each other, and undergo interactions and collisions.
- Separations across intergalactic distances range from 50 kpc up to 1 Mpc.
- ALFALFA science goals include studying the effects within the group environment –
  - What is HI mass function?
  - How do unseen HI clouds/starless galaxies effect dynamics?
  - Are there unseen tidal remnants or debris?
  - What are sizes of HI disks?

Groups of galaxies



cz = -34 km/s

M66 Group: The Leo Triplet



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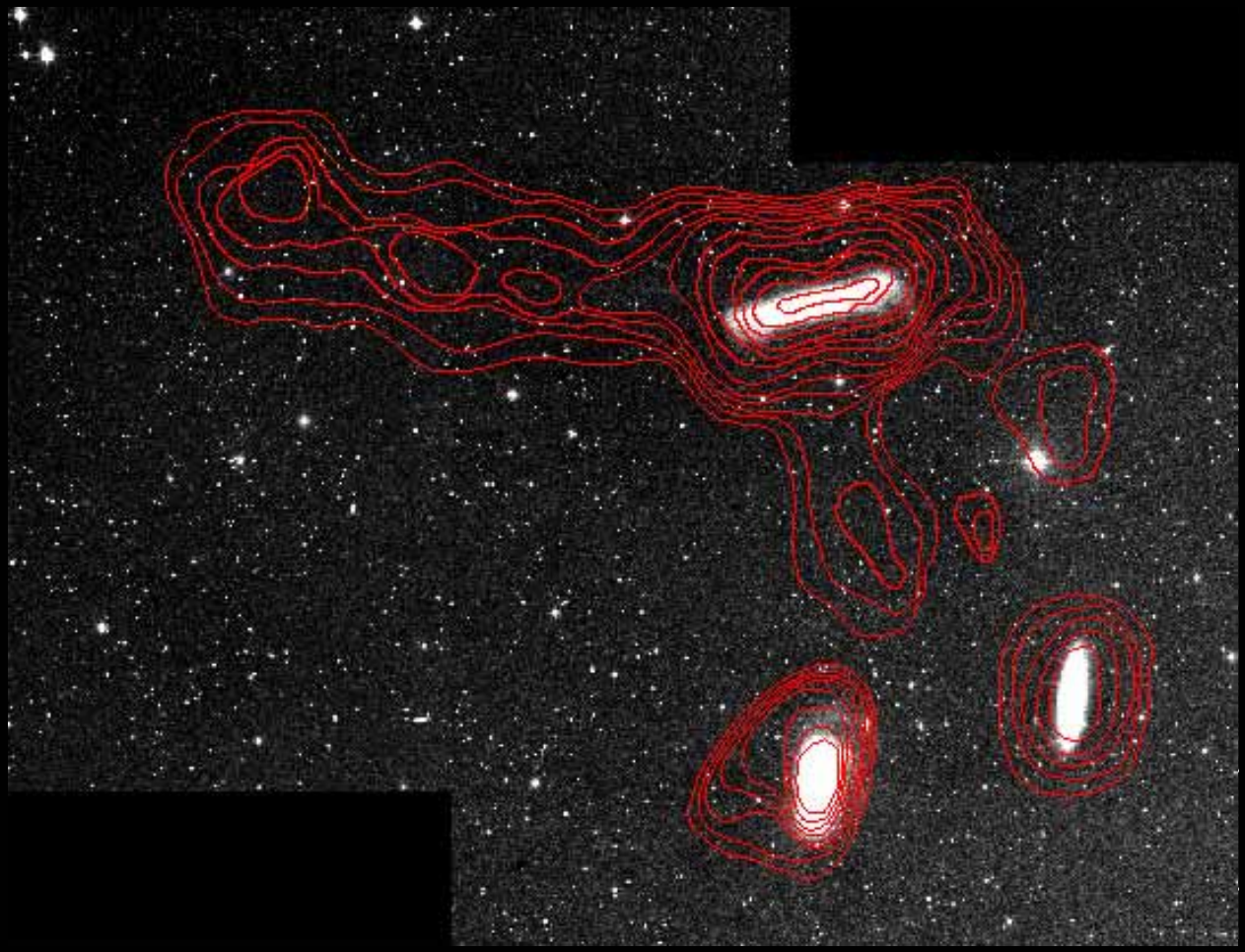
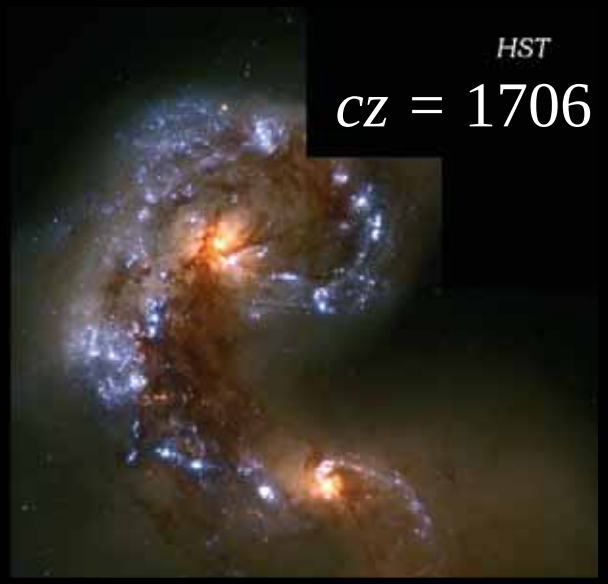


Colliding Galaxies: The Antennae



cz = 1706 km/s

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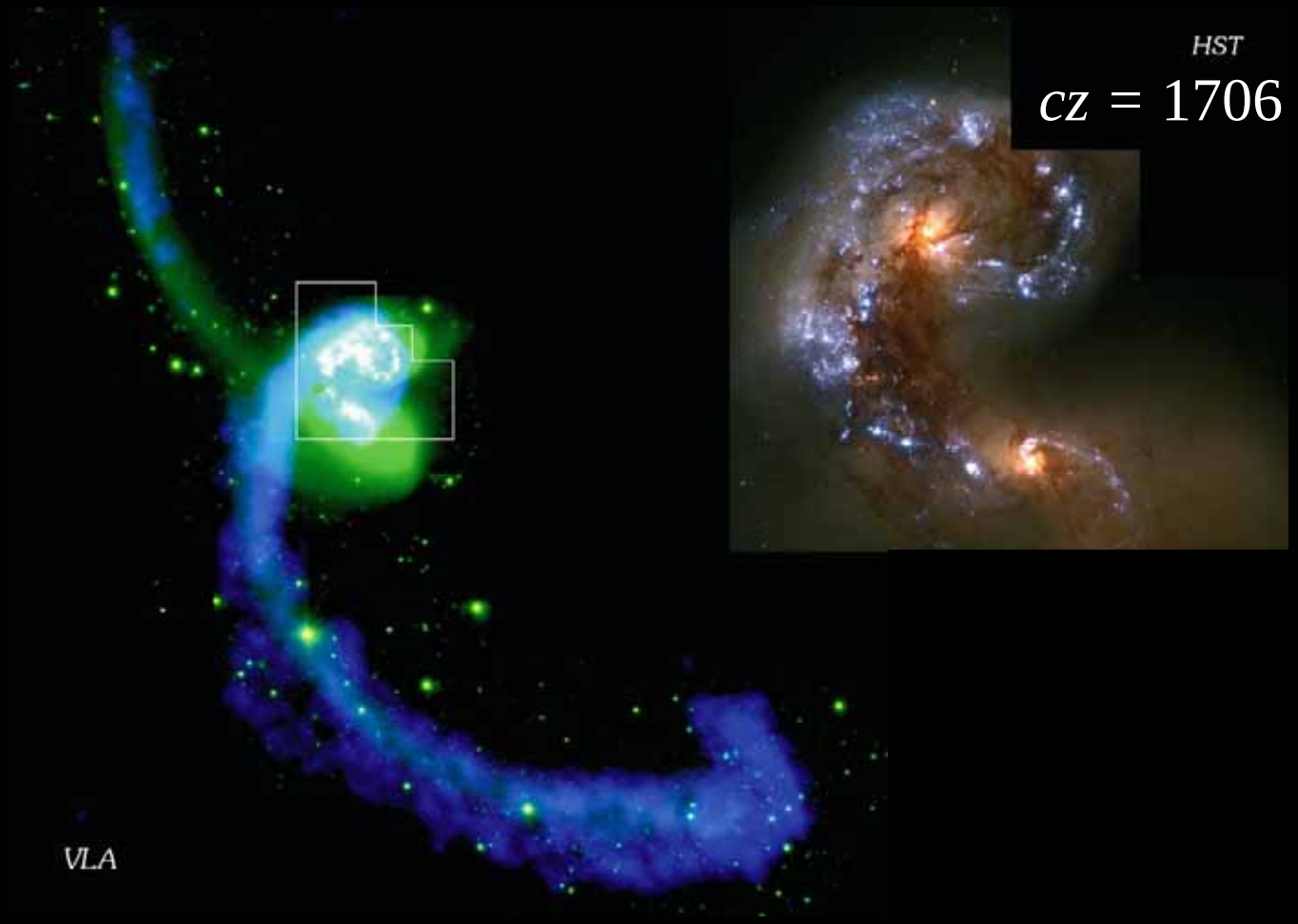

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Distribution of Galaxies

- Structures in the Universe: The best place to find a galaxy is next to another one!
  - Groups
  - **Clusters**
  - Superclusters
  - Filaments and Voids

The Virgo Cluster is the closest nearby cluster, at about 17 Mpc. It contains about 1500 member galaxies!

Clusters of Galaxies

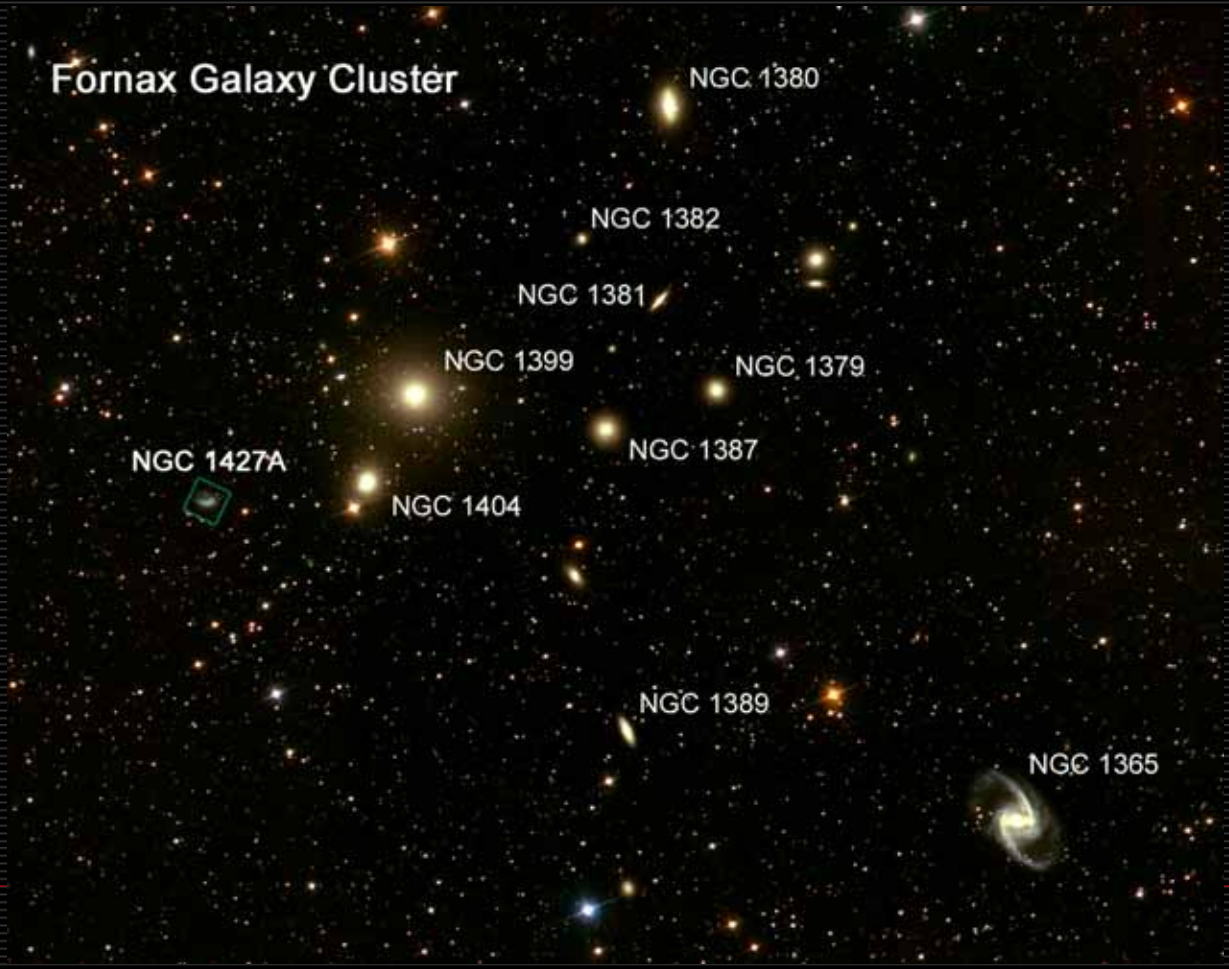
- Around half the galaxies in the Universe are found in clusters or groups.
- Clusters have a higher density than “loose” groups – brightest galaxies are S0s and ellipticals instead of spirals
- Abell Catalog contains 4073 rich clusters
- Gravity binds the members, as well as hot intracluster gas (seen in the X-ray)

Virgo Cluster

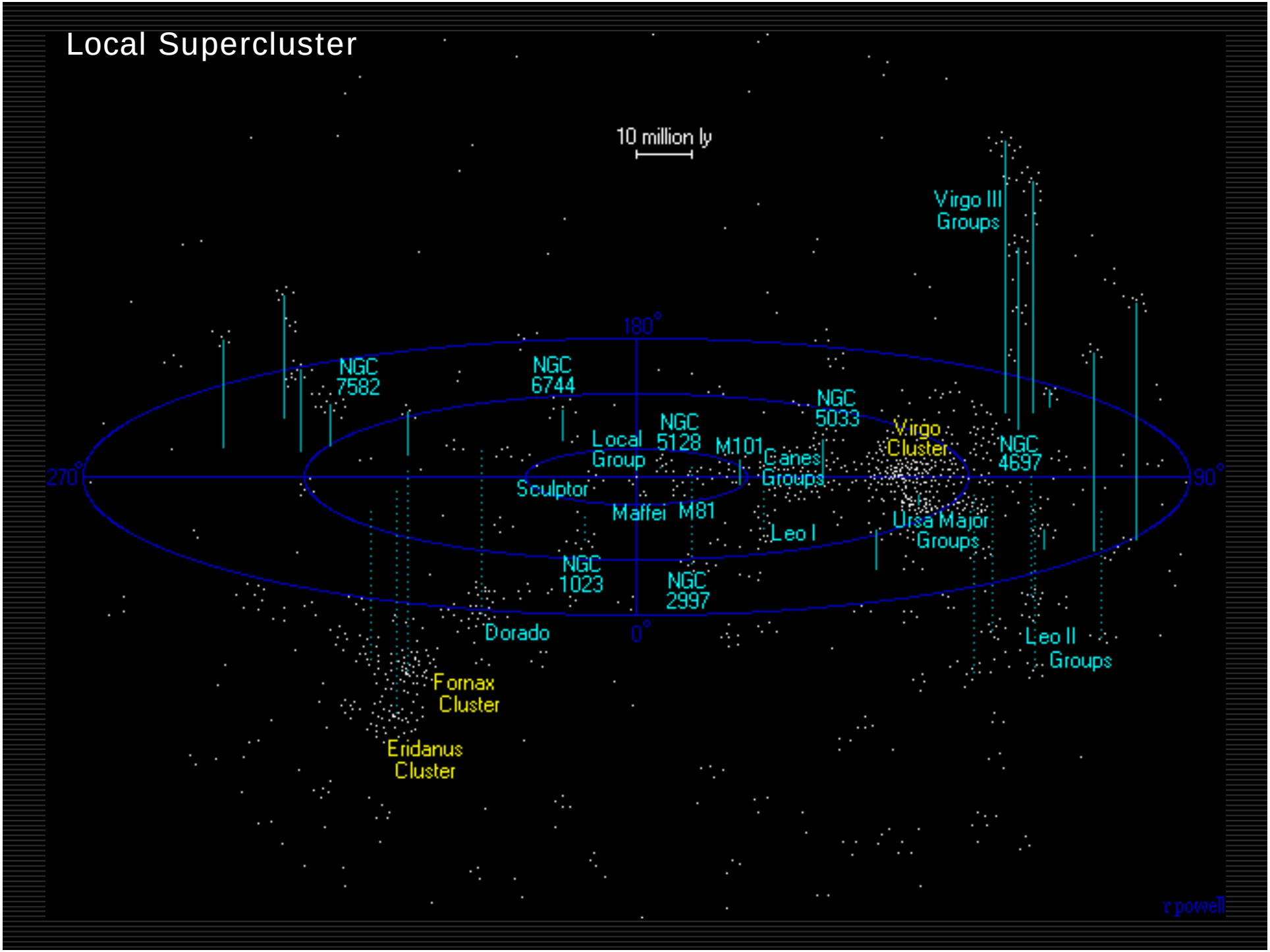
- cz ~ 1035 km/s
- Δv ~ 1000 km/s
- 1300 catalogued members
- Most galaxies are dwarf elliptical type

Fornax cluster

- *cz* ~ 1400 km/s



Local Supercluster



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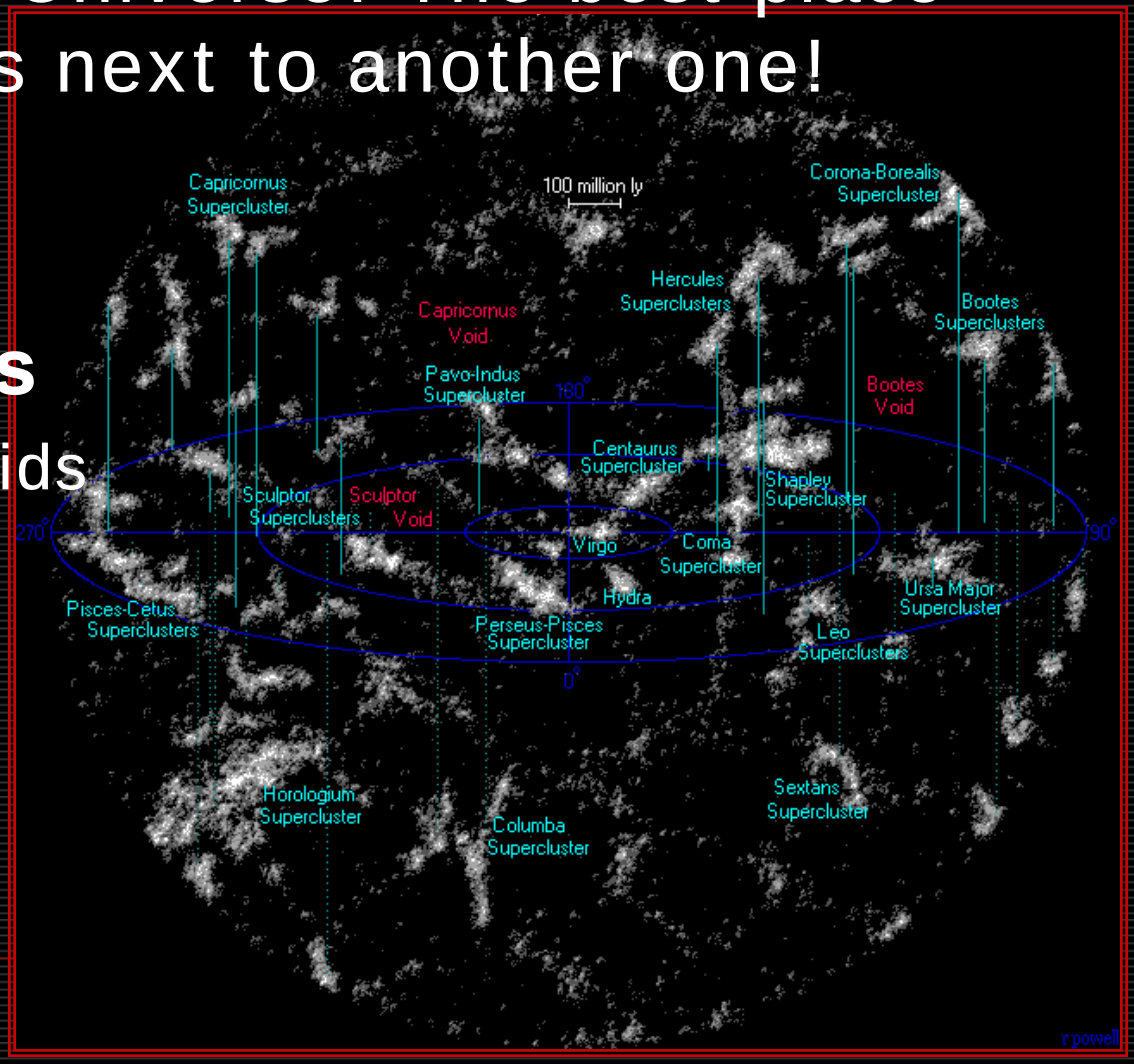

Superclusters are "clusters of clusters" and can extend for hundreds of millions of light years.

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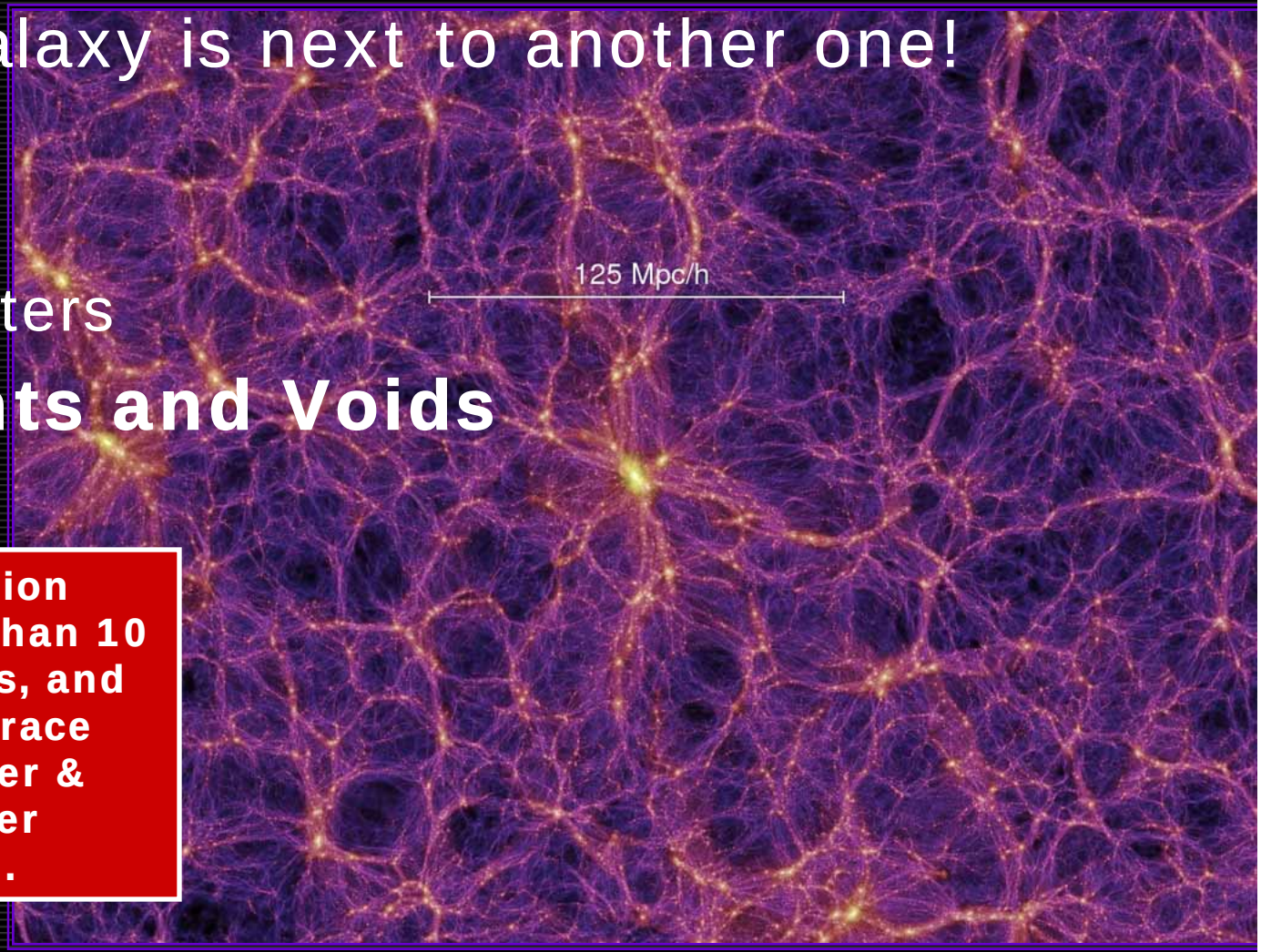
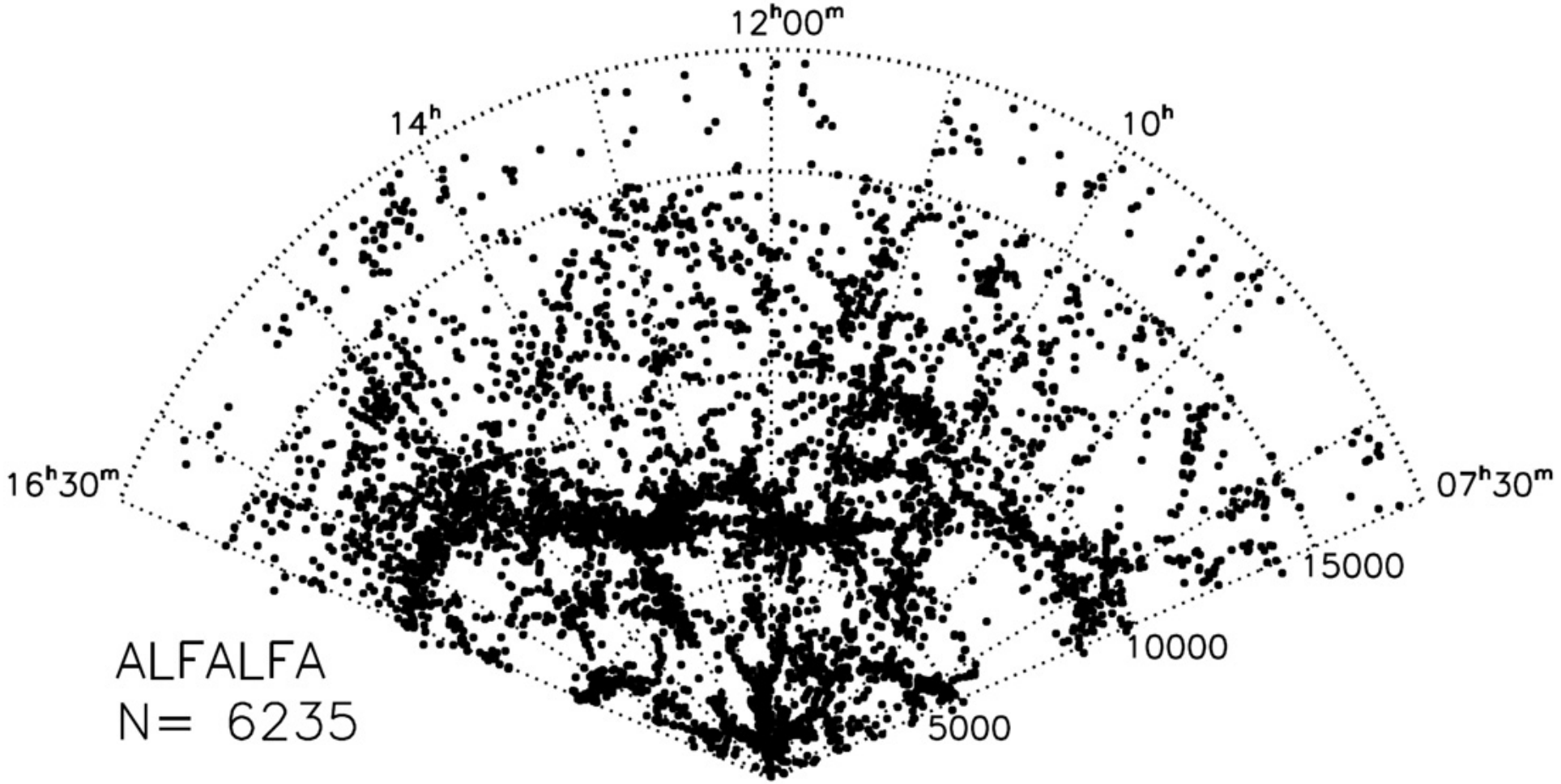


This simulation contains more than 10 billion particles, and attempts to trace galaxy, cluster & supercluster formation.

ALFALFA View of the Local Universe



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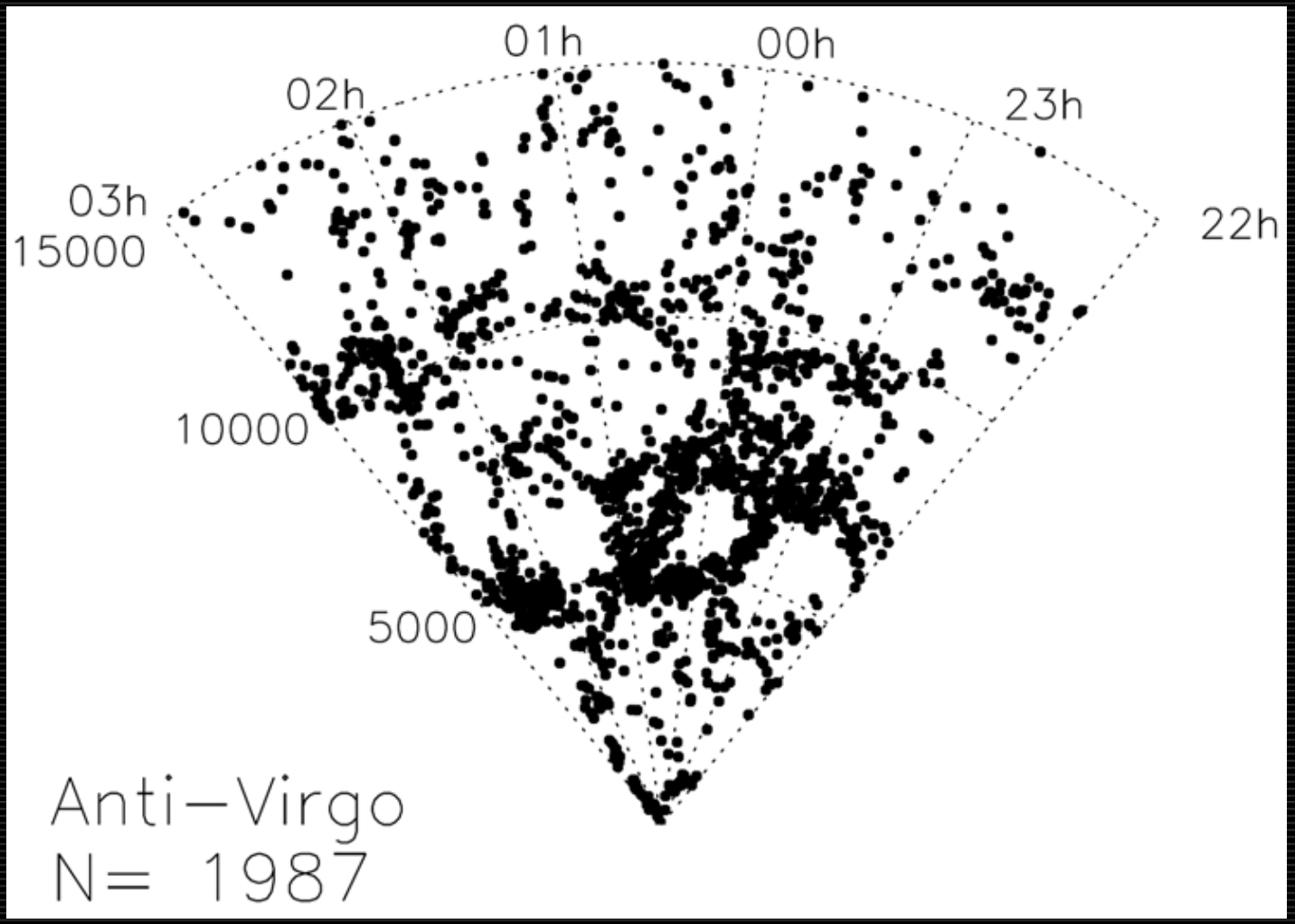

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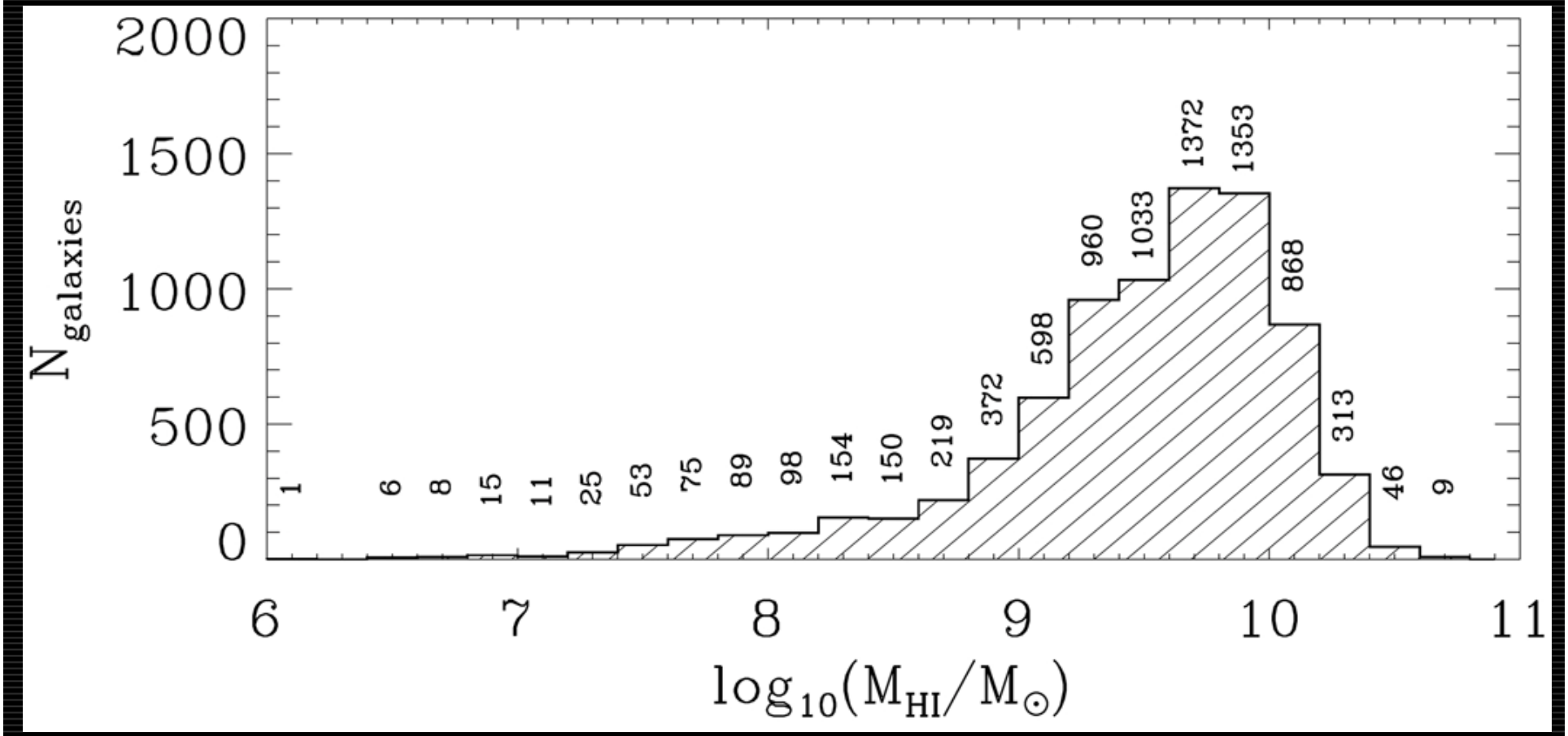

ALFALFA View of the Local Universe