

# The Local Universe

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2009 Undergraduate ALFALFA Workshop  
(thanks to Brian Kent!)

# What is a Galaxy?

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

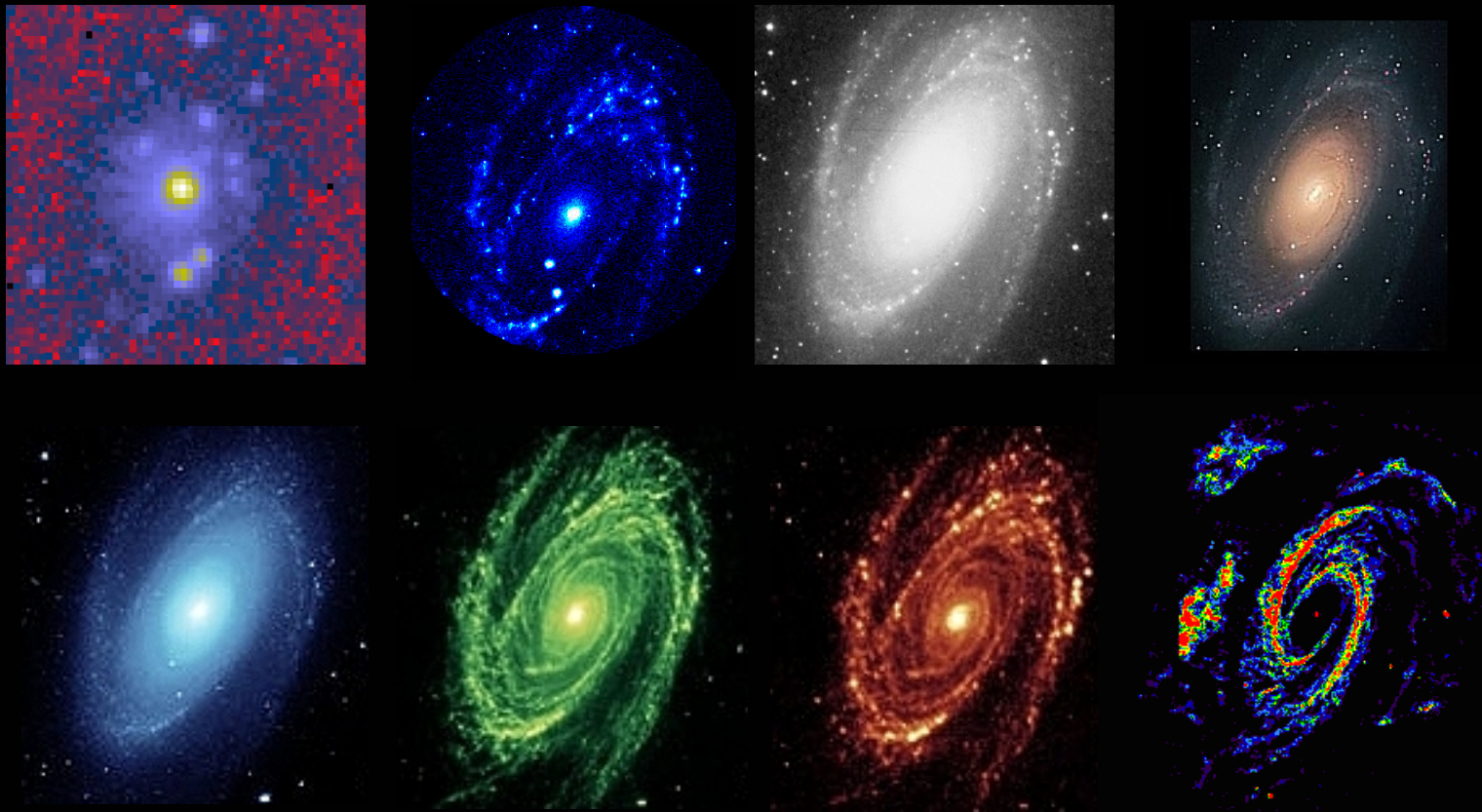


M31, from Hubble

# What do Galaxies Look Like?

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



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From the IPAC Multiwavelength Museum



# Types of Galaxies

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□ From dwarfs to giants, from spirals to ellipticals

Andromeda, a spiral galaxy, with a nearby dwarf elliptical



# Types of Galaxies: Spirals

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- ❑ 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

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- ❑ 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

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- 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

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



LMC and SMC

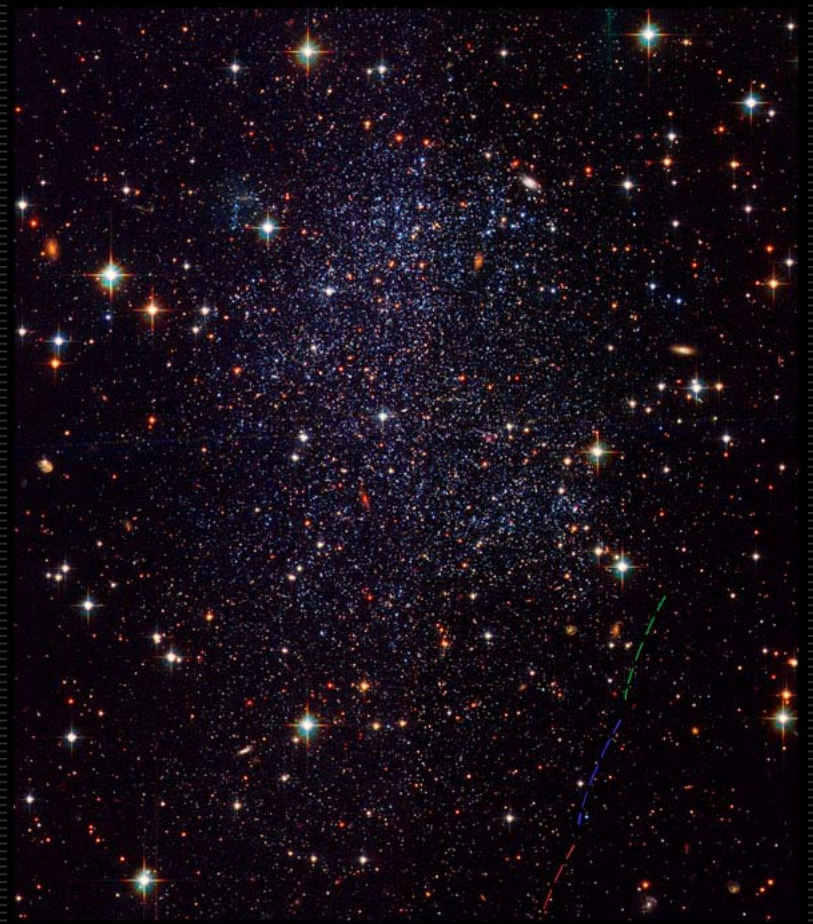


# Dwarf Galaxies

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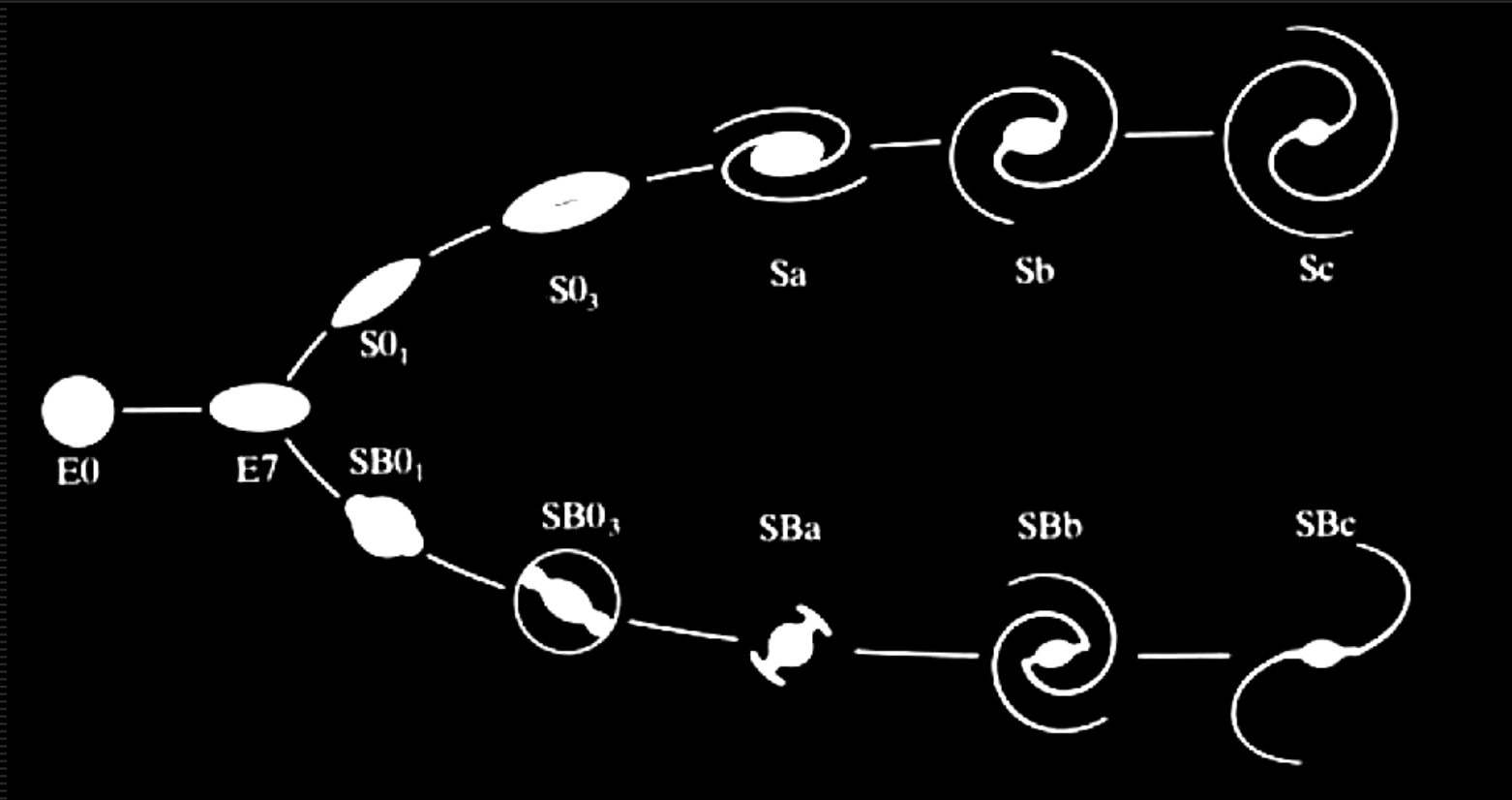
- **Smaller size** than giant galaxies
- Lower **surface brightness**
- **Most common galaxies!**

M32



Sagittarius Dwarf

# The Hubble Tuning Fork



Early Type

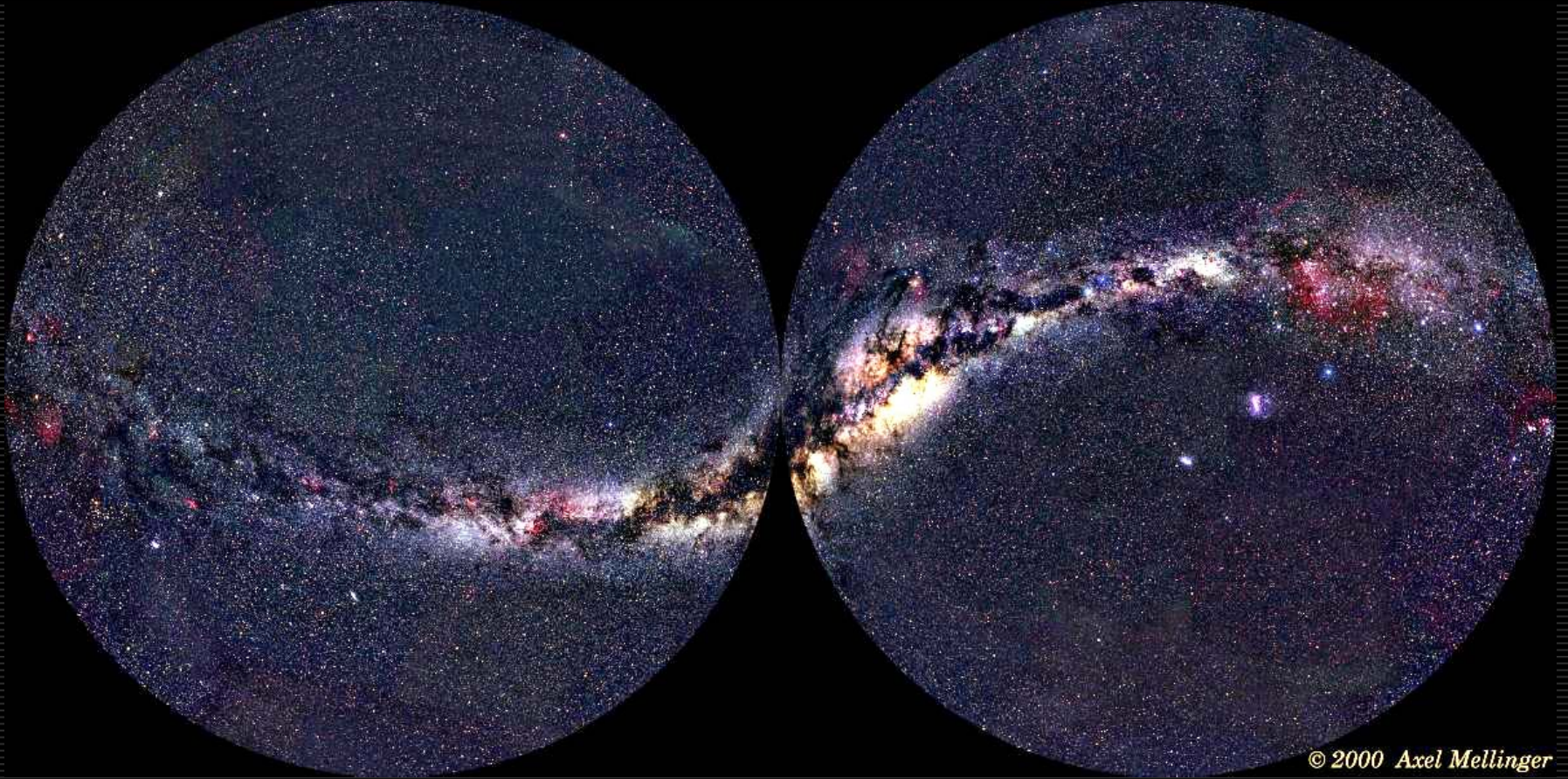
Late Type



# Our Galaxy: The Milky Way

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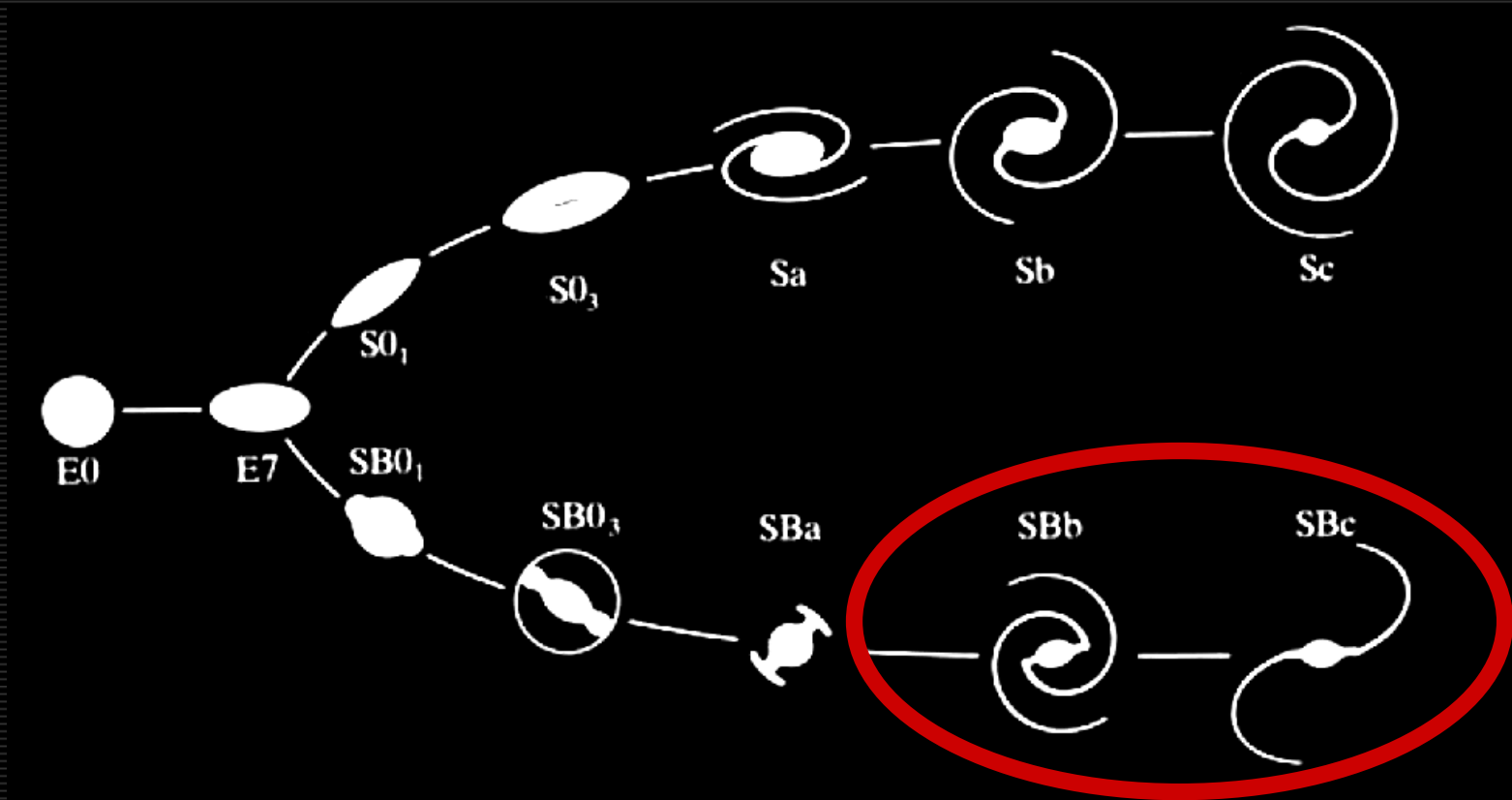
- An Sbc galaxy that is 30 kpc in diameter



© 2000 Axel Mellinger



# The Hubble Tuning Fork

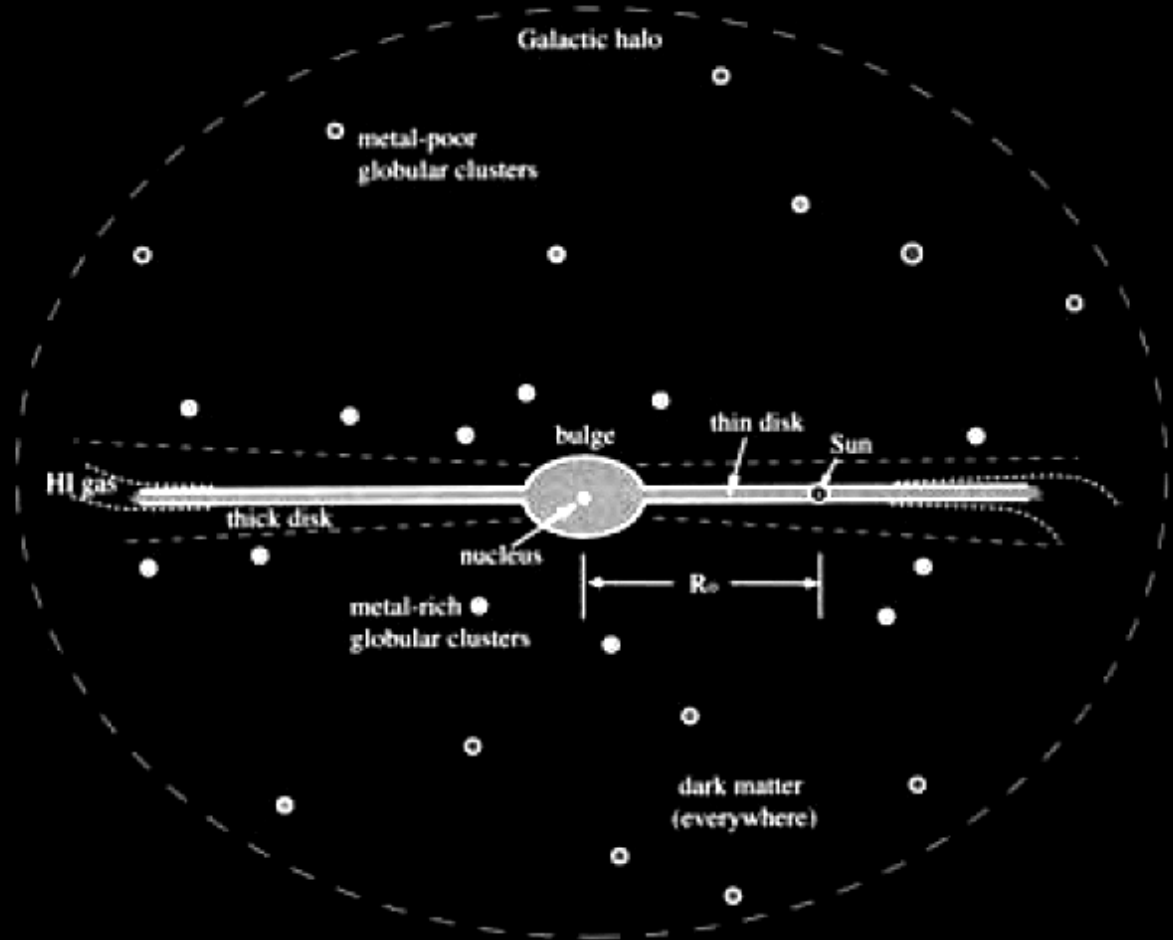


Early Type

Late Type

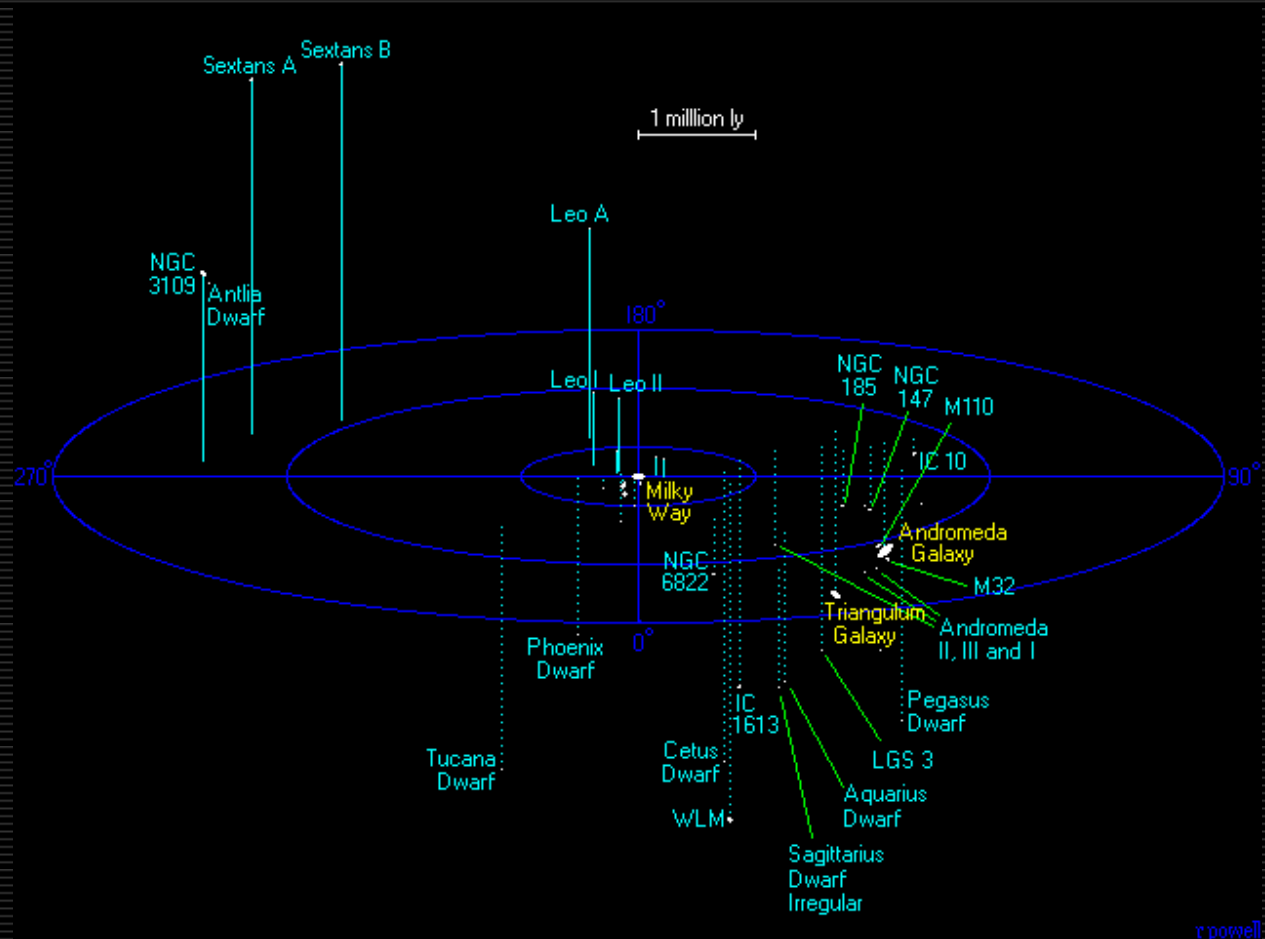
# Anatomy of the Milky Way

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



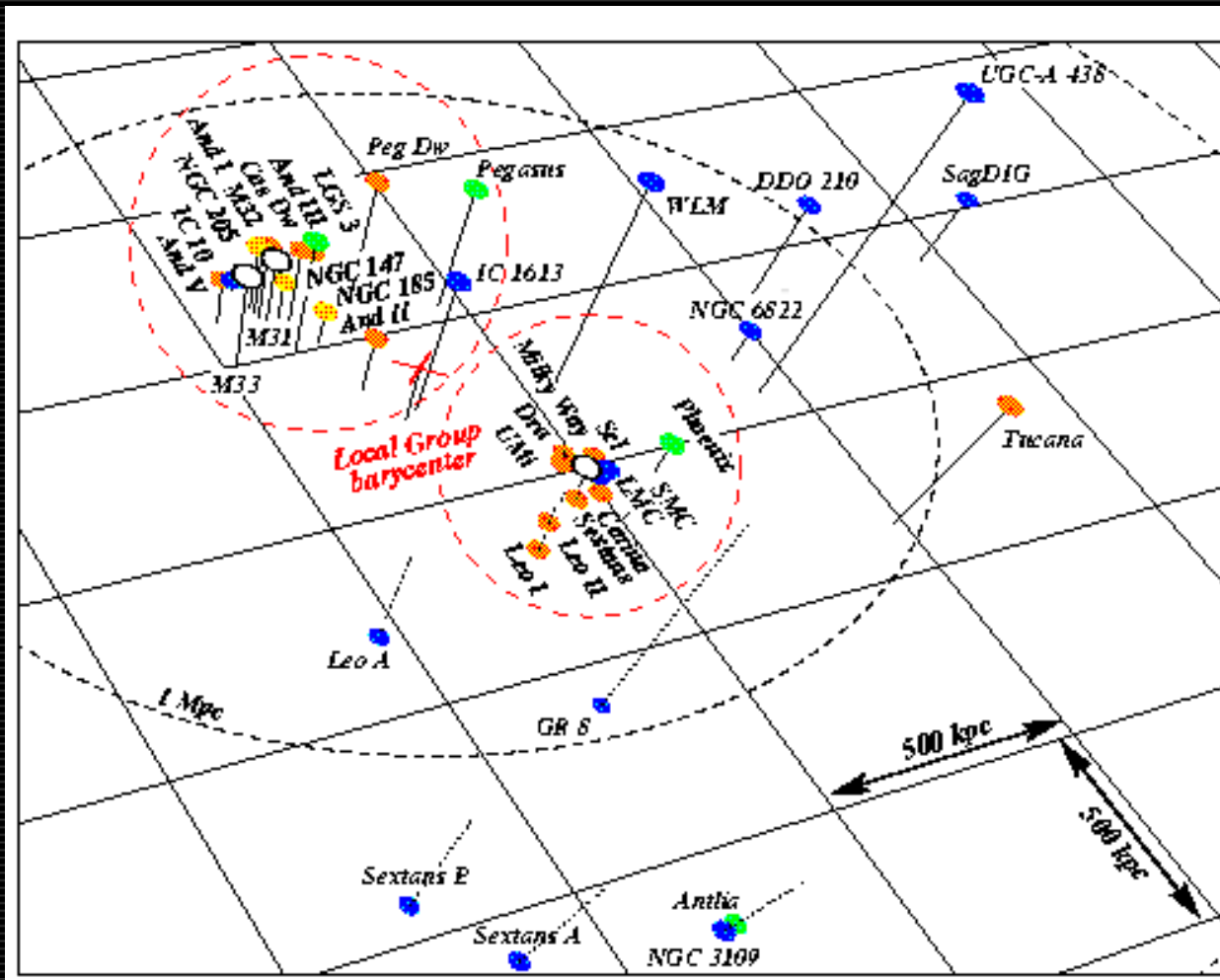
# Our Neighborhood: The Local Group

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





# Our Neighborhood: The Local Group



- Giant spirals
- dSph (+dEII)
- dIrr
- dIrr/dSph

# The Andromeda Galaxy

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- ❑ 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!

$$cz = -300 \text{ km/s}$$

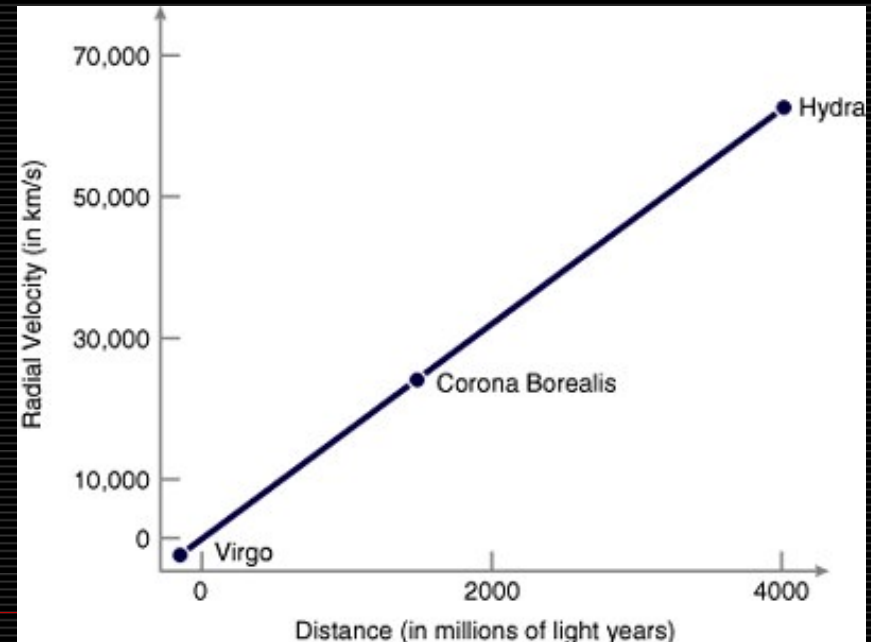


# Another Contribution from Hubble . . .

□ The Universe is expanding!

□ Edwin Hubble showed the Universe was **expanding**!

$$cz = H_0 d$$





# A simple calculation: Redshift

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

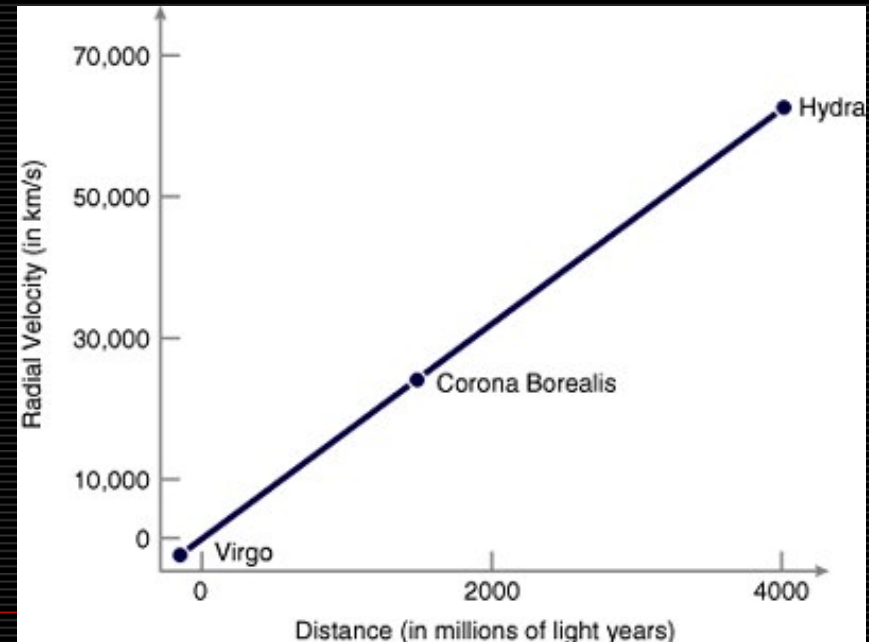
- ❑ Measure the shift in a spectral line –  $f_0$  is the rest frequency  
( $\lambda_0$  the rest wavelength)
- ❑ **Extragalactic objects** often identified by their  $cz$  measurement.
- ❑ ALFALFA will cover  $cz = -2000$  to  $17000$  km/s (out to 250 Mpc)

# Another Contribution from Hubble . . .

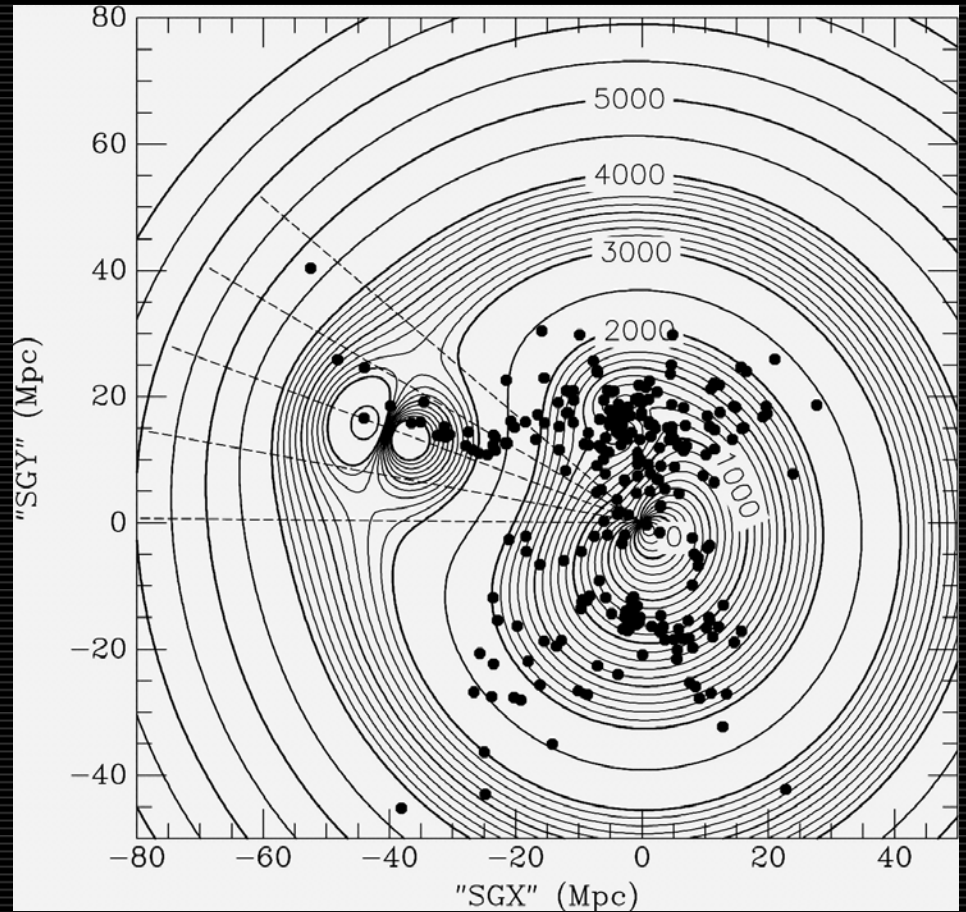
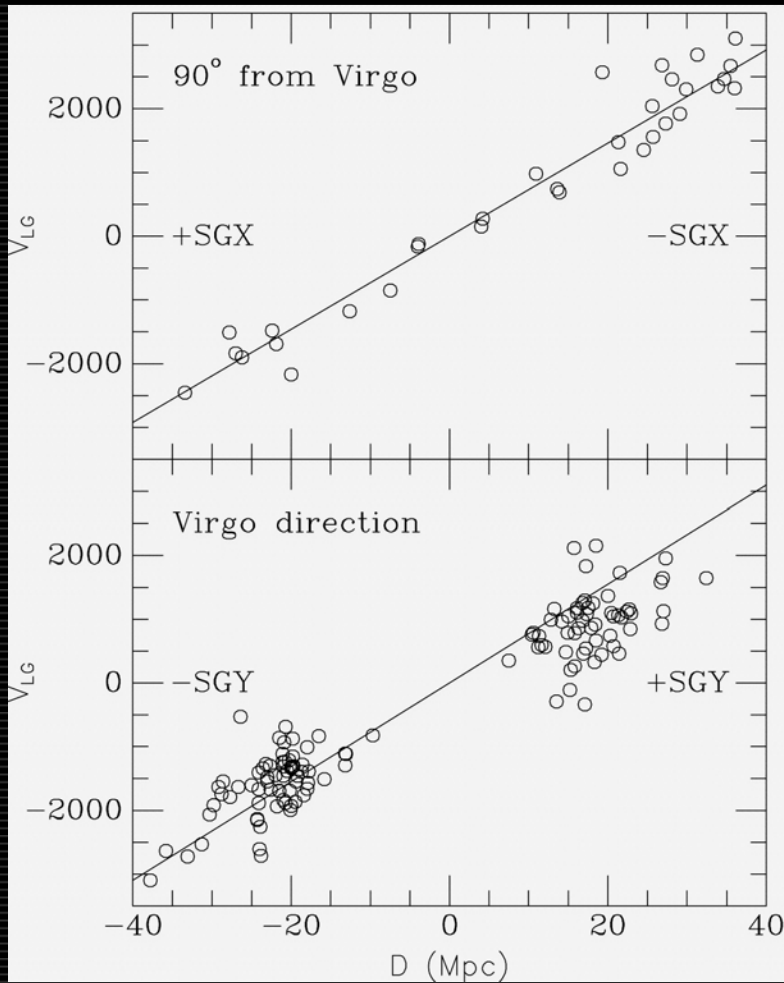
## □ The Universe is expanding!

- Edwin Hubble showed the Universe was **expanding**!
- 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.

$$cz = H_0 d$$



# Distances to nearby galaxies



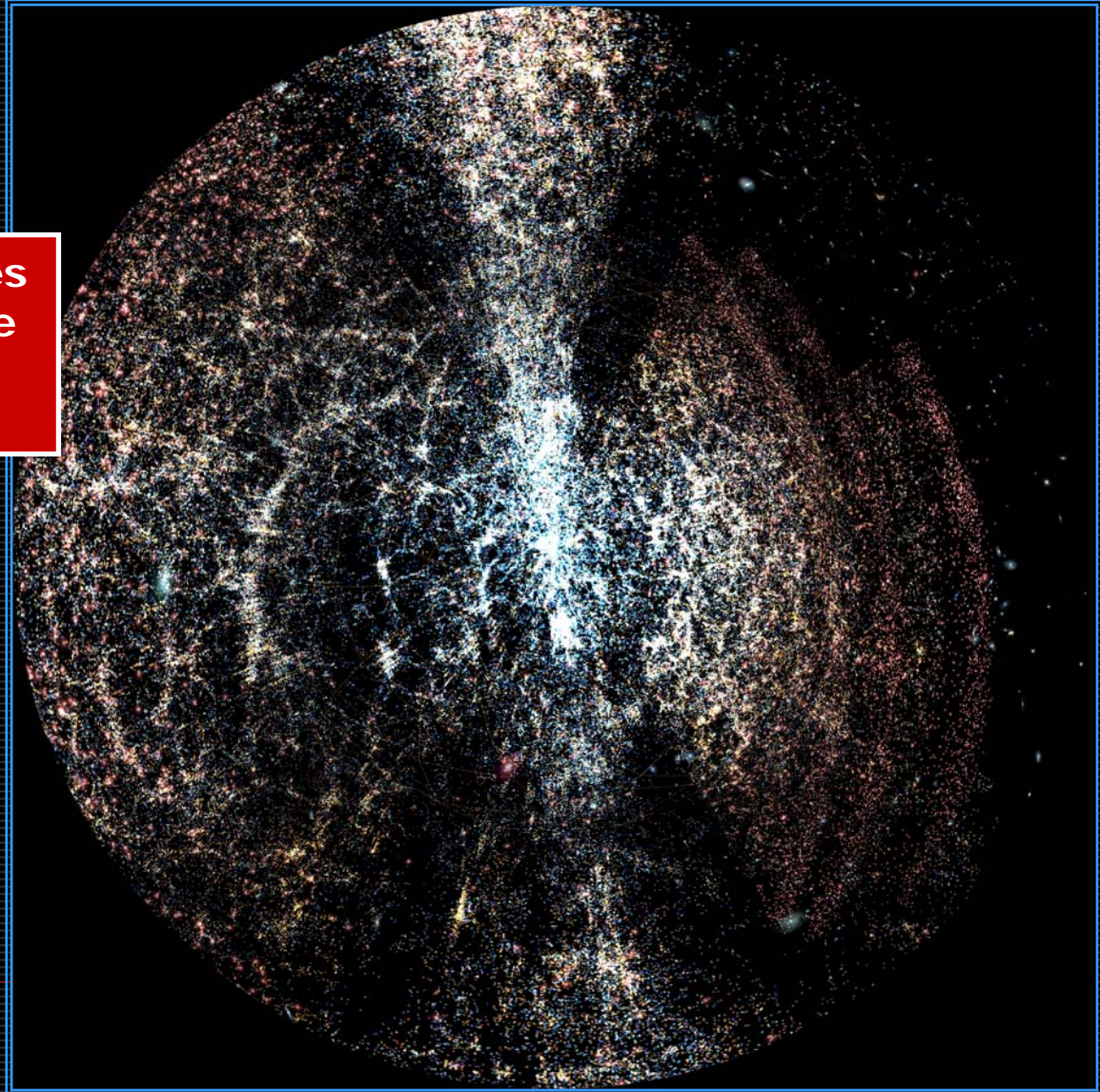
*Tonry, et al. 2000*



# Distribution of Galaxies

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



# Distribution of Galaxies

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- 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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# Distribution of Galaxies

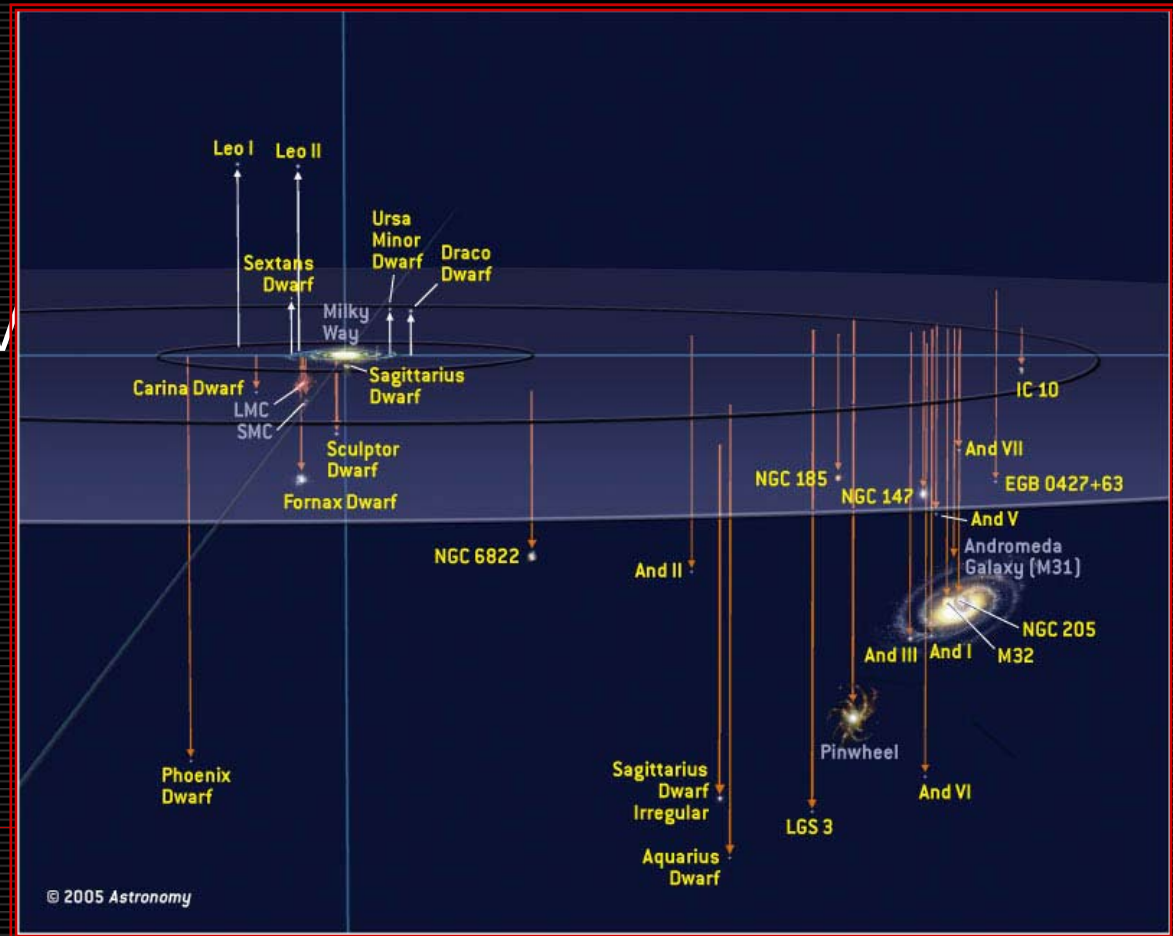
□ Structures in the Universe: The best place to find a galaxy is next to another one!

## ■ Groups

## ■ Clusters

## ■ Superclusters

## ■ Filaments and Voids



# Groups of galaxies

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- 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 affect dynamics?
    - Are there unseen tidal remnants or debris?
    - What are sizes of HI disks?
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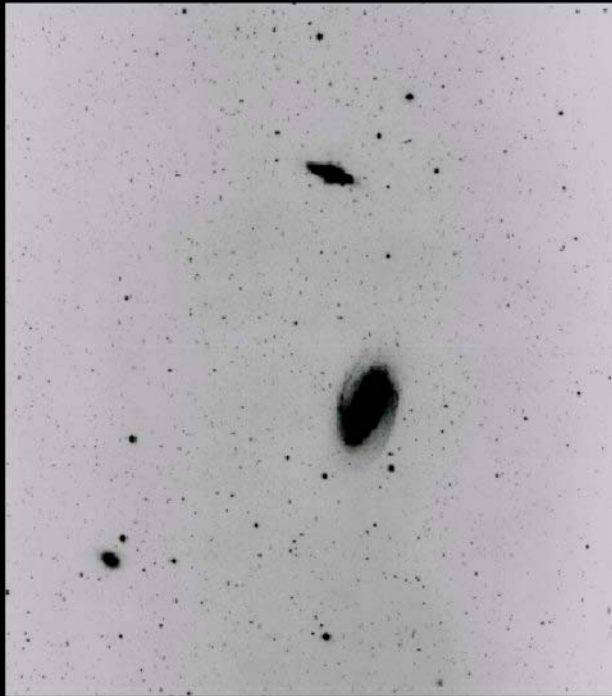


# Groups of galaxies

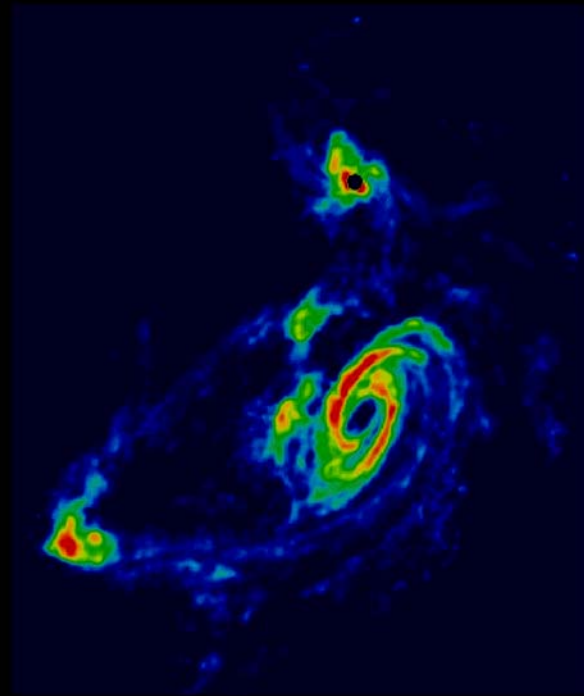
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## TIDAL INTERACTIONS IN M81 GROUP

Stellar Light Distribution



21 cm HI Distribution

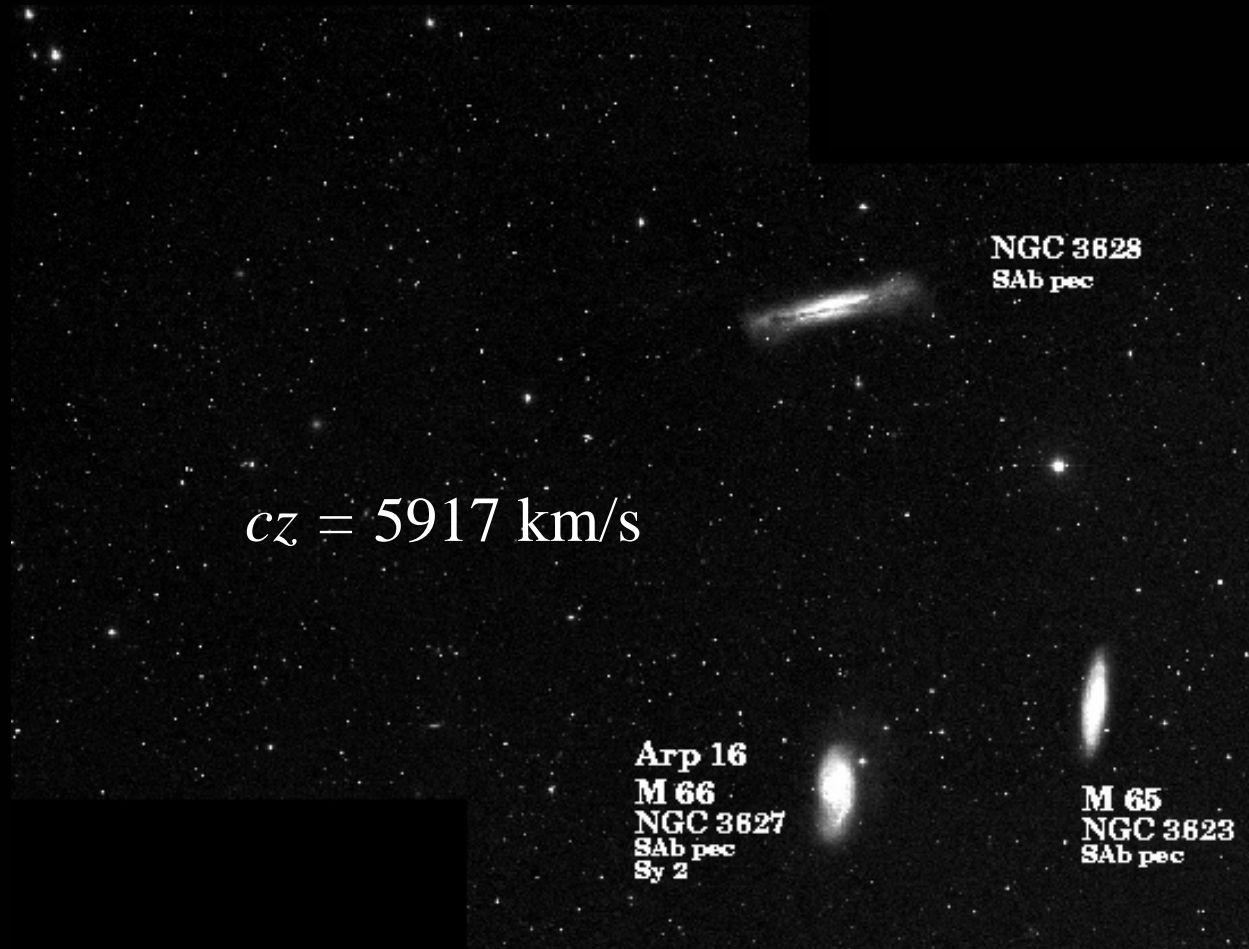


$cz = -34$  km/s

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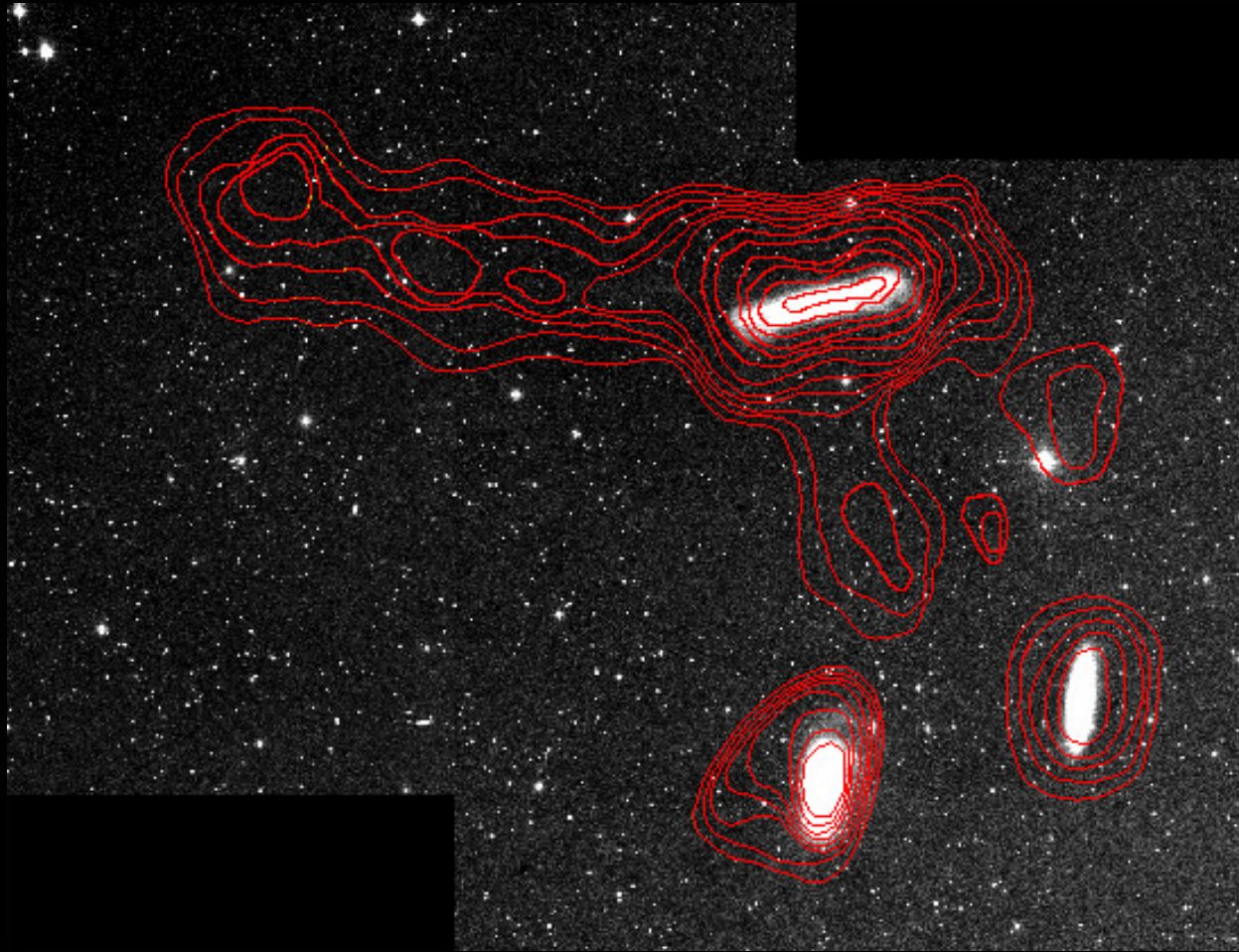
# M66 Group: The Leo Triplet

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# M66 Group

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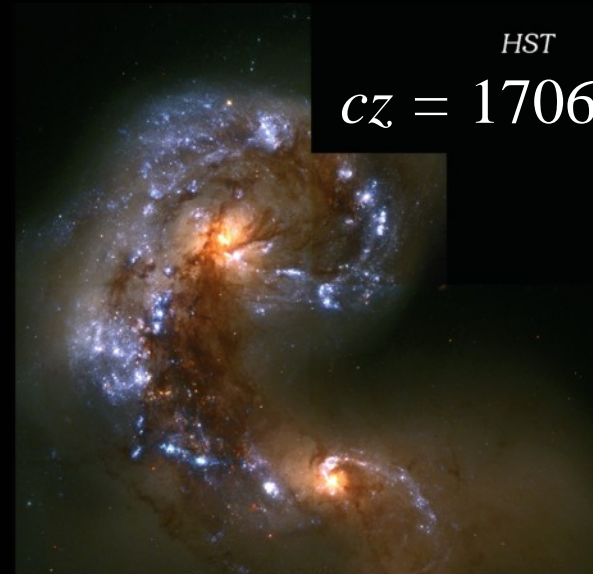






# Colliding Galaxies: The Antennae

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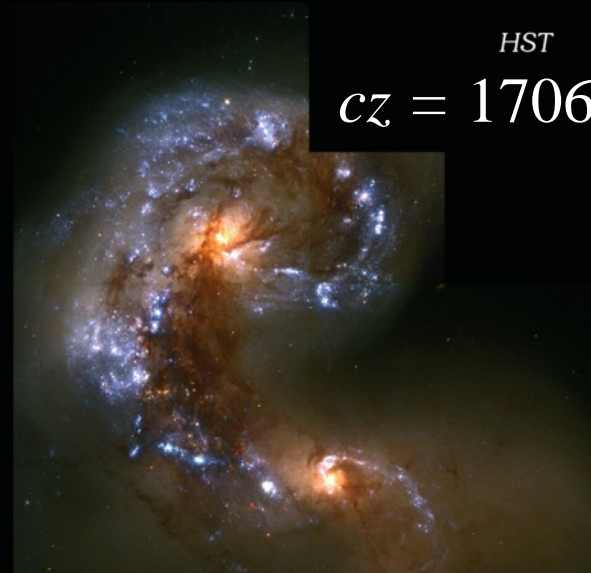
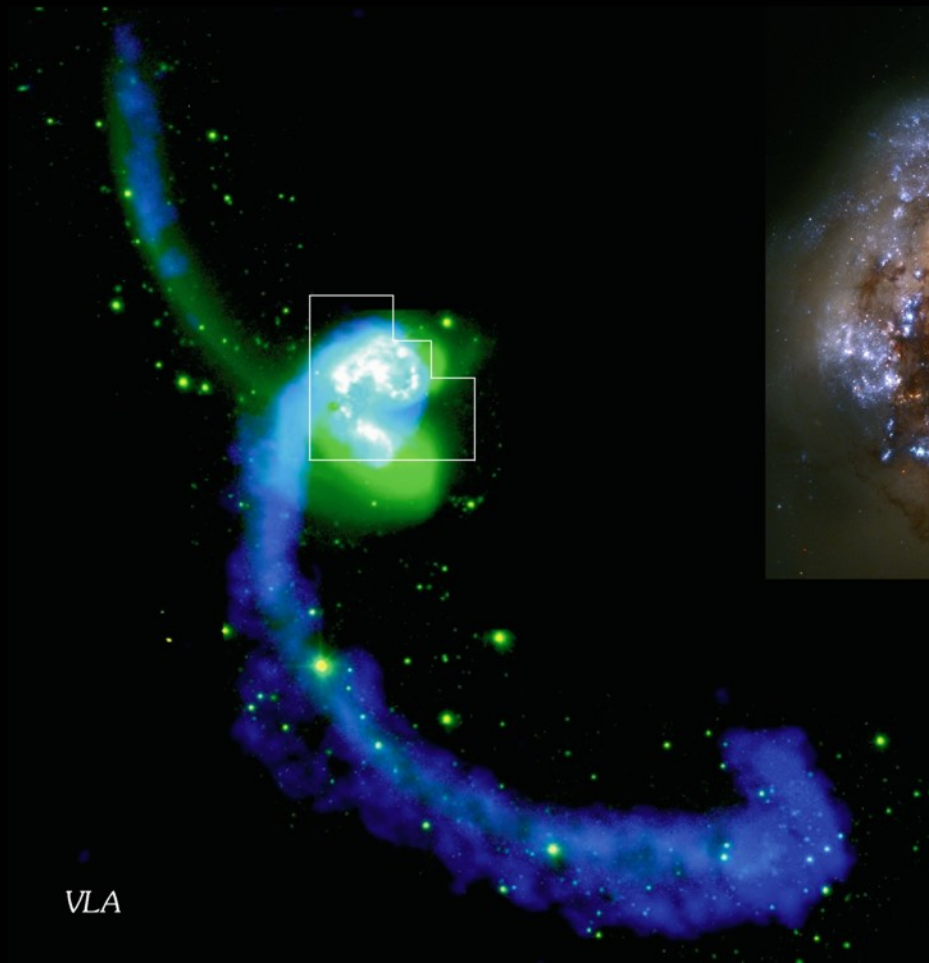
*HST*

$cz = 1706 \text{ km/s}$

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# Colliding Galaxies

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$c z = 1706 \text{ km/s}$

# 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

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- ❑ 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)
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# Virgo Cluster

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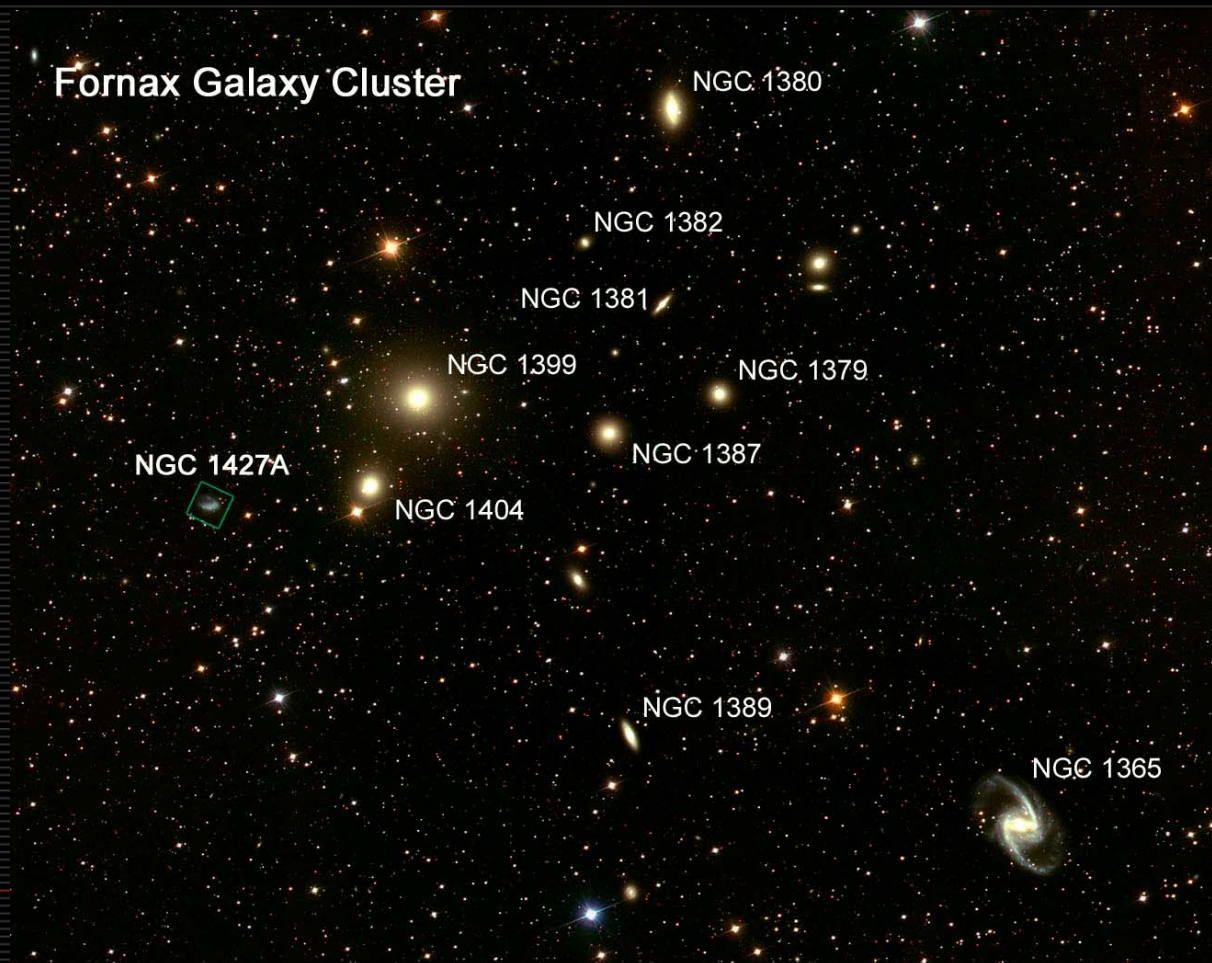
- ❑  $cz \sim 1035$  km/s
- ❑  $\Delta v \sim 1000$  km/s !!
- ❑ 1300 catalogued members!!
- ❑ Most galaxies are dwarf elliptical type
- ❑ Core radius  $\sim 500$  kpc

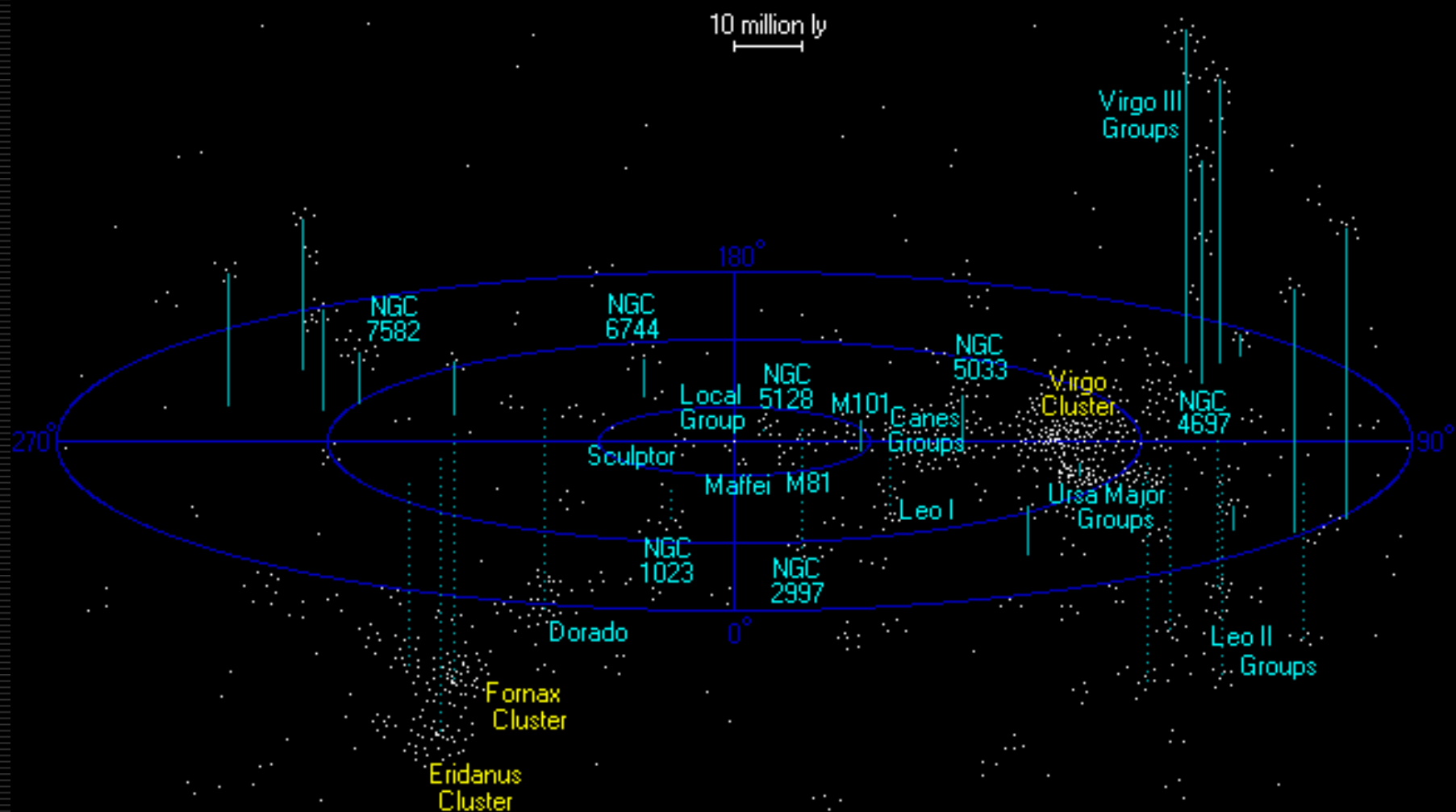


# Fornax cluster

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□  $cz \sim 1400$  km/s





# 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

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

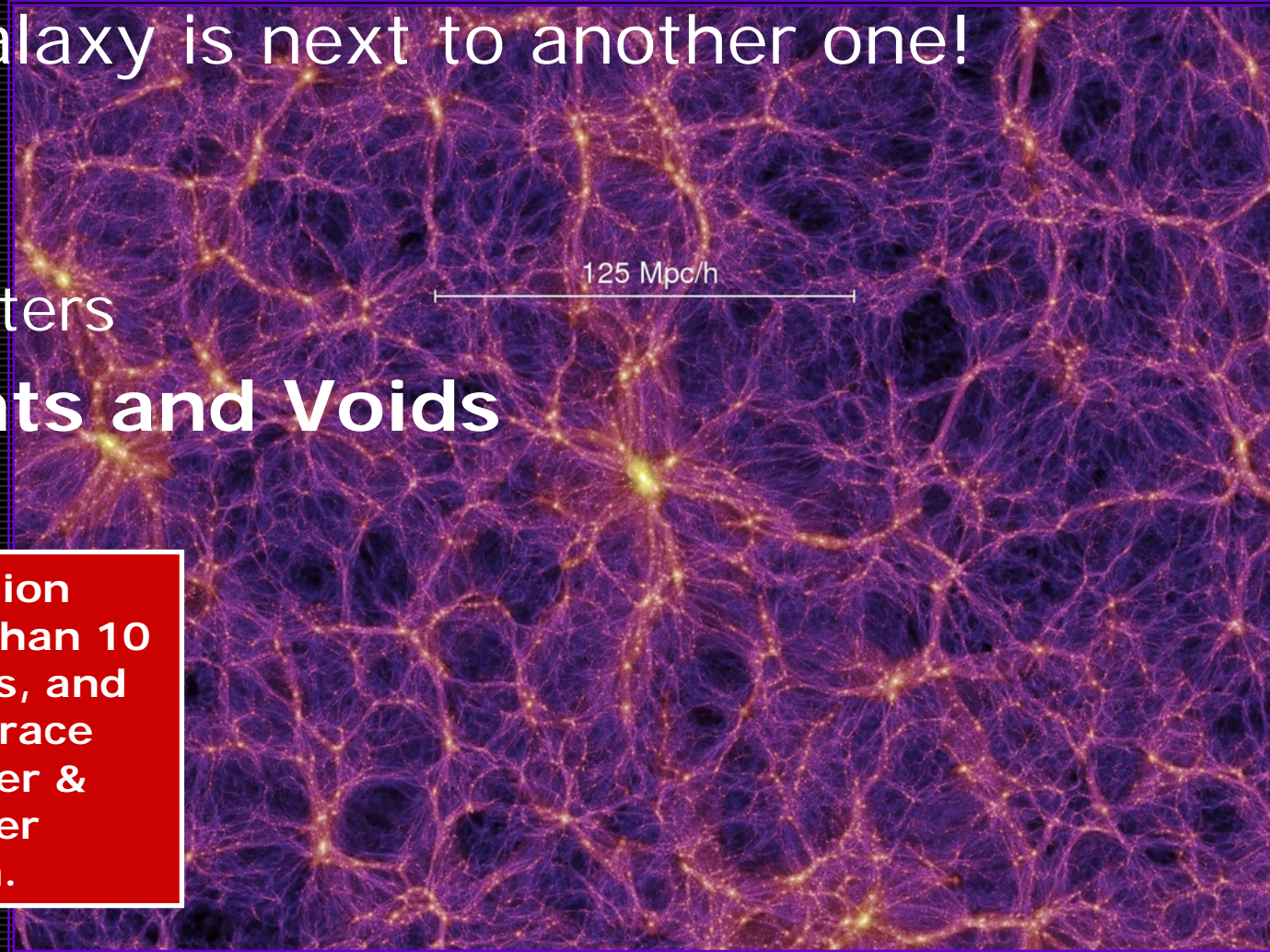




# Distribution of Galaxies

□ Structures in the Universe: The best place to find a galaxy is next to another one!

- Groups
- Clusters
- Superclusters
- **Filaments and Voids**



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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