The Local Universe

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(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?

Images:
- M51
- NGC 1365
- M33
- M33 (© IAC/ROG/Marin)
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.
Dwarf Galaxies

- 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

- An Sbc galaxy that is 30 kpc in diameter
The Hubble Tuning Fork

Early Type

Late Type
Anatomy of the Milky Way

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

- 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

\[ z = \frac{\lambda_{\text{obs}} - \lambda_0}{\lambda_0} = \frac{f_0 - f_{\text{obs}}}{f_{\text{obs}}} \]

- 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

~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
Distribution of Galaxies

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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

TIDAL INTERACTIONS IN M81 GROUP
Stellar Light Distribution  21 cm HI Distribution

$cz = -34 \text{ km/s}$
M66 Group: The Leo Triplet

\[ cz = 5917 \text{ km/s} \]
M66 Group
Colliding Galaxies: The Antennae

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

\[ cz = 1706 \text{ km/s} \]
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

- 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

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

- $cz \sim 1400 \text{ km/s}$
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

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

ALFALFA
N = 6235