# Plan of Lecture

## Properties of Other Galaxies I

Night labs.

Shapley-Curtis debate.

"Normal" (not active) galaxies.

Demographics.

Globular clusters.

## Night Labs

Yes, we'll do actual observing!

Thursdays, starting at 9 PM.

**Sign up tomorrow in section.**

Will try starting Thursday, April 15.

**Repeat until we get good weather!**

Due date: one week after observing.

## Early Observations

Stars are points, even in the best telescopes.

However, early telescopes showed that some objects are diffuse and extended.

**Generically called "nebulae".**

Early catalog: Messier, 103 objects not to be confused with comets!

Some of these are known to be local.

**M1: Crab nebula.**

**M42: Orion nebula.**

**M15: globular cluster.**

But others were of unknown type.

## Setting for a Debate

By 1908, nearly 15,000 "nebulae" were cataloged.

Were some of these "island universes" on par with our Milky Way?

What is the scale of the universe?

On April 26, 1920, in Washington, DC, a debate on these issues was held between Harlow Shapley and Heber Curtis.

Some of the data discussed included:

**Slipher: redshifts.**

**Observations of globulars.**

**Rotation of spiral nebulae.**

## Shapley's Points

Harlow Shapley was the younger astronomer.

Based on globulars, Shapley thought the Milky way was 100 kpc in diameter.

**Sun 20 kpc from center.**

**Based on Cepheid distances.**

Shapley thought this was so large it had to be basically the whole universe.

**Other nebulae couldn't be that big.**

Shapley's friend Adriaan Van Maanen measured rotation of spiral nebulae.

**If too distant, faster than c!**

Why redshifts for many spiral nebulae?

**Shapley: blown away by radiation.**

## Curtis's Points

Curtis was more established.

Based on star counts, Curtis held traditional view:

**Milky way is 10 kpc in diameter.**

**Sun is near center.**

High speeds measured by Slipher not consistent with motion inside our galaxy.

Did not believe Cepheids were good distance measures.

Did not believe Van Maanen's rotation measurements; too small to be reliable.

## Resolution of the Debate

Shapley focused on size of Milky Way, and he was closer to right.

**Key: understanding of absorption.**

**Calibration of Cepheids.**

Curtis focused on the nature of the spiral nebulae, and he was right.

**Key: Cepheids in other galaxies.**

**Hubble, 1924.**

**Estimated Andromeda at 400 kpc.**

Van Maanen's rotation measures were just wrong.

**Hairy edge of data!**

## The Local Group

Our first opportunity to look at more galaxies is local.

Within $\sim 1$ Mpc, there are $\sim 30$ galaxies.

Milky Way is large; near it are many small galaxies.

**Many have $M < 0.01\ M_{\rm MW}$!**

Nearest spiral is Andromeda, M31.

**$\sim$50% bigger than Milky Way.**

**Small galaxies around it.**

Some of the small galaxies are irregulars; many are dwarf ellipticals.

Are these characteristics typical of galaxies elsewhere?

## Galaxy Characteristics

Compiled from large surveys of galaxies.

Spirals: $\sim 77\%$ of galaxies.

$M \sim 10^9 - 10^{12}\, M_\odot$.

**Young and old stars in disk.**

**Have ISM in disk.**

Ellipticals: $\sim 20\%$ of galaxies.

$M \sim 10^5 - 10^{13}\, M_\odot$**!**

**Mostly old stars.**

**Very little ISM.**

Irregulars: $\sim 3\%$ of galaxies.

$M \sim 10^8 - 10^{10}\, M_\odot$.

**Mostly young stars.**

Ellipticals are more common in clusters.

## Luminosity Distribution

In the Local Group there are more small things than big. Is this typical?

Suppose we count up the number of galaxies $dN$ between luminosities $L$ and $L + dL$.

$dN/dL \sim L^{-1} e^{-L/L_*}$.

$L_* \approx L_{\rm M31}$.

This is the "Schechter function".

**Galaxies not arbitarily large!**

Difficult to count faint galaxies.

Recent evidence suggests the slope flattens at very faint galaxies.

**Still, most galaxies are small.**

## Galactic Cannibalism

As we've pointed out, galaxies can be quite close together and collide.

When small galaxies hit big ones, they are "eaten".

For two ellipticals, little gas, so only stellar orbits are disturbed.

But for spirals, ISMs collide as well.

**Shocks, high density.**

**Lots of star formation!**

Locally, evidence that MW is shredding nearby dwarf galaxies.

**Magellanic Stream.**

## Globular Clusters

These are not considered galaxies, but are nonetheless groups of stars.

**Mass** $\sim 10^4 - 10^6\, M_\odot$**.**

**All old stars.**

Galaxies have many around them.

**Milky Way has** $\sim 150$**.**

**Andromeda has** $\sim 400$**!**

Extremely closely packed stars.

$\sim 10^3 - 10^6$ **per cubic parsec!**

Roughly spherically distributed around Milky Way.

## Summary

Nature of "nebulae" debated in early 20th century.

Local Group contains many small galaxies, two big ones.

In universe as a whole, spirals are most common.

**Challenge:** why are ellipticals more common in clusters?