Plan of Lecture
Our Milky Way Galaxy

Seeing the forest past the trees: the system of stars we live in.

Basics of the Milky Way.

Size, mass, age, etc.

How do we know these?

Formation ideas.

Spiral arms.

The Galactic nucleus.

Supermassive black holes.

Basics of Our Galaxy

A galaxy is a collection of a billion to a trillion stars, bound together by their gravity.

Also has gas, dust, debris.

Our Milky Way is about 50,000 parsecs in diameter.

Mass: about 100 billion $M_\odot$ in stars, smattering in gas, dust.

Probably 11-13 billion years old.

Solar system: 4.5-5 billion years.

Universe: ≈15 billion years.

Shape: flattened (disklike), with spiral-like bright regions (spiral arms).

We orbit center, 250 km/s.

Discovery of Our Galaxy

??? “Discovery”? It’s all around us, so how could we avoid seeing it?

Look at night sky: stars everywhere.

Hazy band: the Milky Way.

People thought stars went on forever.

Also, that we were at center.

In 1700s, realization: fewer stars in some directions than in others.

Are we in the middle of a disk?

Is the universe finite?

Are We At The Center?

The first quantitative attempt to determine location was made by William Herschel.

Reasoning: we know MW isn't sphere, because we see more stars in a band than away from band.

If we're in a disk, we should see more stars towards center than away.

Herschel looked at 683 star fields.

$\sim$same number in all directions!

We are in center.

In early 1900s, Kapteyn reached same conclusion.

Standard Candles

Are we in the center of the stars, or not?

To know, we must measure distances accurately to get a 3-D map. But how?

Parallax restricted to close stars.

"Standard candle", star type of known brightness? Apparent brightness gives distance.

Henrietta Leavitt (1868-1921).

Cepheid variables (change brightness)

Luminosity$\longleftrightarrow$variation time.

Cepheids are standard candles!

Basis of much of cosmology.

More on Cepheids

How can a *variable* star be a standard candle?

Consider the mechanism for Cepheids.

Start with "small", hot atmos.

Helium is ionized.

High opacity; lots of e^-.

Pushed out by radiation.

Cools, becomes neutral.

Fewer e^-; sinks down.

This mechanism repeats on roughly a free fall time.

$T \sim \sqrt{R^3/GM} \sim \sqrt{1/G\rho}$.

Bigger, less dense, stars pulsate slower!

Our Location in the Milky Way

One important type of collection of stars is globular clusters.

$10^5 - 10^6$ stars within 20 pc.

Harlow Shapley (1885-1972) noticed that most of these are in one part of the sky.

Why? If they orbit around the Galactic center, must mean we're off-center!

But how far? Using variable stars, Shapley found that we are well away from center.

Modern distance: maybe 7 kpc = 7,000 pc.

Galactic center: in Sagittarius.

Once again, we aren't at the center.

Through a Glass, Darkly

So what went wrong for Herschel and Kapteyn?

They would have been fine if they could have seen all stars equally well.

But interstellar medium acts like a fog.

See only nearby stars.

View not obscured through *thickness* of disk, but it is through the *radius* of disk.

How can we deal with this?

Globular clusters.

Infrared, radio, X-ray.

The Shape of the Milky Way

The Milky Way looks like a disk with a bulge.

Disk is $\sim$50 kpc in diameter.

Disk is $\sim$0.6 kpc thick.

Central bulge is $\sim$2 kpc in diameter.

In addition, there are globular clusters and dwarf galaxies extending hundreds of kiloparsecs out.

Halo of Milky Way.

Then there are those spiral arms...

Spiral Arms

The Milky Way is called a spiral galaxy, because of its spiral arms.

Again, these are tough to see; can see more easily in other, similar galaxies.

Look at bright stars, and use radio maps.

But what are spiral arms?

Even worse: outer parts of Galaxy rotate slower than inner.

Why don't arms wind up?

Partial answer: arms are regions of star formation.

Bright now because of hot stars.

When hot stars die, arms fade.

The Nucleus

All visible stars orbit the center of the galaxy.

But, *very* different from Solar System:

Sun is most of mass.

In Galaxy, mass is distributed.

Nearer center than we are, there are more stars in a given volume.

Also, thickness of Galaxy puffs up.

Center is obscured by dust, gas.

Use infrared, radio.

At very center, a mysterious radio source...

Supermassive black hole!

3 million $M_\odot$.

See stars move fast around it.

Formation and Age of Milky Way

Substantial uncertainty. Some clues:

Galaxy is flattened, disklike.

Stars rotate around center.

Sounds like Solar System... maybe Milky Way formed from rotating cloud of gas?

Could be, but data are incomplete. Lots of work on this.

Okay, then, how long did it have to form?

Age is inferred indirectly:

Radioactive dating.

Heavy elements in stars.

Cooling of white dwarfs.

Result: 11-13 billion years, about.

Summary

Our Milky Way contains about 400 billion stars.

It is 25,000 parsecs in diameter; we are 2/3 of the way out.

It is about 11-13 billion years old.

It has spiral arms and a nucleus that probably contains a huge black hole.

Challenge: what is the average star in our Galaxy? **Hint**: need to define "average"!