19.3 The History of the Milky Way

Our goals for learning:

- What clues to our galaxy's history do halo stars hold?
- How did our galaxy form?
What clues to our galaxy's history do halo stars hold?
Halo Stars:
0.02–0.2% heavy elements (O, Fe, ...), only old stars

Disk Stars:
2% heavy elements, mostly young stars
Halo Stars:
0.02–0.2% heavy elements (O, Fe, …), only old stars formed first, then stopped.

Disk Stars:
2% heavy elements, mostly young stars
Halo Stars:
0.02–0.2% heavy elements (O, Fe, ...), only old stars

Disk Stars:
2% heavy elements, mostly young stars

Halo stars formed first, then stopped.

Disk stars formed later, kept forming.
How did our galaxy form?
Our galaxy formed from a cloud of intergalactic gas.
Halo stars formed first as gravity caused gas to contract.
Remaining gas settled into a spinning disk.
Stars continuously form in disk as galaxy grows older.
Stars continuously form in disk as galaxy grows older.

Warning: This model is oversimplified!
Detailed studies show that halo stars formed in clumps that later merged.
What have we learned?

- What clues to our galaxy’s history do halo stars hold?
  - Halo stars are all old, with a smaller proportion of heavy elements than disk stars, indicating that the halo formed first.

- How did our galaxy form?
  - Halo stars formed early in the galaxy’s history; disk stars formed later, after much of the galaxy's gas settled into a spinning disk.
19.4 The Mysterious Galactic Center

Our goals for learning:

What lies in the center of our galaxy?
What lies in the center of our galaxy?
Radio emission from center  Swirling gas near center

50 light-years  10 light-years
Swirling gas near center

Orbiting stars near center

10 light-years

1 light-year
Stars appear to be orbiting something massive but invisible... a black hole?

Orbits of stars indicate a mass of about 3 - 4 million $M_{\text{Sun}}$. 

© 2014 Pearson Education, Inc.
X-ray flares from galactic center suggest that tidal forces of suspected black hole occasionally tear apart chunks of matter about to fall in.
What have we learned?

- What lies in the center of our galaxy?
  - Orbits of stars near the center of our galaxy indicate that it contains a black hole with 4 million times the mass of the Sun.
Galaxies and the Foundation of Modern Cosmology
20.1 Islands of Stars

Our goals for learning:

- How are the lives of galaxies connected with the history of the universe?
- What are the three major types of galaxies?
- How are galaxies grouped together?
How are the lives of galaxies connected with the history of the universe?
Hubble Deep Field

- Our deepest images of the universe show a great variety of galaxies, some of them billions of light-years away.
Galaxies and Cosmology

- A galaxy's age, its distance, and the age of the universe are all closely related.

- The study of galaxies is thus intimately connected with cosmology—the study of the structure and evolution of the universe.
What are the three major types of galaxies?
Hubble Ultra Deep Field
Disk component: stars of all ages, many gas clouds

Spheroidal component: bulge and halo, old stars, few gas clouds
Disk component: stars of all ages, many gas clouds

Spheroidal component: bulge and halo, old stars, few gas clouds

Blue-white color indicates ongoing star formation

Red-yellow color indicates older star population
Disk component: stars of all ages, many gas clouds

Spheroidal component: bulge and halo, old stars, few gas clouds

Blue-white color indicates ongoing star formation

Red-yellow color indicates older star population
Thought Question

Why does ongoing star formation lead to a blue-white appearance?

A. There aren't any red or yellow stars.
B. Short-lived blue stars outshine the others.
C. Gas in the disk scatters blue light.
Thought Question

Why does ongoing star formation lead to a blue-white appearance?

A. There aren't any red or yellow stars.
B. **Short-lived blue stars outshine the others.**
C. Gas in the disk scatters blue light.
Galaxy Zoo – Spirals (Sc)
Galaxy Zoo – Spirals (SBb)
Galaxy Zoo – Spirals (Sa)
Lenticular galaxy: has a disk like a spiral galaxy but much less dusty gas (intermediate between spiral and elliptical)
Elliptical galaxy: all spheroidal component, virtually no disk component.

- Red-yellow color indicates older star population.

M87, a giant elliptical galaxy in the Virgo Cluster, is one of the most massive galaxies in the universe. The region shown is more than 300,000 light-years across.
Galaxy Zoo – Ellipticals (E4)
Galaxy Zoo – Ellipticals (E9)
Galaxy Zoo - Irregular

Blue-white color indicates ongoing star formation.
Galaxy Zoo - Irregular
Hubble's galaxy classes

Spheroid dominates

Disk dominates

NOT Evolutionary Sequence
How are galaxies grouped together?
Spiral galaxies are often found in *groups* of galaxies (up to a few dozen galaxies).
Elliptical galaxies are much more common in huge clusters of galaxies (hundreds to thousands of galaxies).
What have we learned?

- How are the lives of galaxies connected with the history of the universe?
  - Galaxies generally formed when the universe was young and have aged along with the universe.

- What are the three major types of galaxies?
  - The major types are spiral galaxies, elliptical galaxies, and irregular galaxies.
  - Spirals have both disk and spheroidal components; ellipticals have no disk.
What have we learned?

How are galaxies grouped together?

- Spiral galaxies tend to collect into groups of up to a few dozen galaxies.
- Elliptical galaxies are more common in large clusters containing hundreds to thousands of galaxies.
The next lecture will cover Chapter 20.2 and 20.3