Announcement

Celebration of Knowledge #3

is coming up on Thu Apr 18.
Start preparing!
This test will cover the classes #15 (Binary Stars) to #20 (Galaxy Evolution) & #21 (Distance Measurement).
50 points, scantron, 1 hr.
Today’s Topics:

• 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?
What is a galaxy?

Galaxies: “Islands of Stars”

“A huge collection of anywhere from a few hundred million (few $10^8$) to more than a trillion stars ($10^{12}$), all bound together by gravity.”
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.
Our deepest image of the universe show a great variety of galaxies, some of them billions of light-years away.
Hubble Ultra Deep Field
Galaxy Morphology

- **Spiral galaxies** -- e.g. *Milky Way*, with disk & spiral arms

- **Elliptical galaxies** -- redder, more round (ellipsoidal shape, like a football), not much gas & dust, but contains hot & ionized gas

- **Irregular galaxies** -- neither disk-like nor elliptical -- disturbed looking

They come in variety of sizes --- giant vs. dwarf galaxies
Spiral Galaxies

NGC 6744

NGC 4414
Spiral Galaxies

**NGC 4594**
(Sombrero Galaxy)
large bulge & halo, dust lane

**NGC 891**
spiral gal seen edge-on dusty lane

~ 25 kpc

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**Disk Component:**
stars of all ages,
many gas clouds

**Spheroidal Component:**
bulge & halo, old stars,
few gas clouds
Barred Spiral Galaxies

NGC 1300: barred spiral galaxy

~ 34 kpc
Elliptical Galaxies
All spheroidal component, no disk component
Red-yellow color indicates older star population

**M87**: giant elliptical galaxy in the Virgo Cluster

**Leo 1**: one of the dwarf galaxies in the Local Group

~ 40 kpc

~ 0.7 kpc
Irregular Galaxies

Blue stars indicate that irregular galaxies are star-forming.

Smaller than typical spiral or elliptical.

Large Magellanic Cloud
small companion to the Milky Way

NGC 1313

~ 9 kpc

~ 15 kpc
Spiral galaxies are often found in groups of galaxies (up to a few dozen galaxies)
Local Group

We have a relatively good map of the nearby universe
Galaxy Cluster

concentration of $\sim 1000$ of galaxies

**Ellipticals** are more common in clusters of galaxies

Abell 1689
size $\sim 2$ Mpc
Hubble Sequence

spheroid dominates

disk dominates

larger bulge, less dusty gas, tighter spiral arms

rounder appearance
Originally people thought that Ellipticals ("early-type") later evolved into spirals ("late-type"), but we now think it’s not that simple...
Quiz

Irregular galaxies are generally

A. more massive than spiral galaxies
B. about the same mass as spiral galaxies
C. less massive than spiral galaxies
In the Hubble sequence, as you move from E0 to E6 type,

A. the shape become rounder.
B. the shape does not change.
C. the shape become less round.
D. the disk become bigger.
E. the disk become smaller.
Lecture-Tutorial (LT): Galaxy Classification (pp.)

- Work with a partner!
- Read the instructions and questions carefully.
- Discuss the concepts and your answers with one another.
- Come to a consensus answer you both agree on.
- If you get stuck or are not sure of your answer, ask another group.
- If you get really stuck or don’t understand what the LT is asking, ask for help.
Welcome to Galaxy Zoo, where you can help astronomers explore the Universe

Galaxy Zoo: Hubble uses gorgeous imagery of hundreds of thousands of galaxies drawn from NASA's Hubble Space Telescope archive. To understand how these galaxies, and our own, formed we need your help to classify them according to their shapes — a task at which your brain is better than even the most advanced computer. If you're quick, you may even be the first person in history to see each of the galaxies you're asked to classify.

More than 250,000 people have taken part in Galaxy Zoo so far, producing a wealth of valuable data and sending telescopes on Earth and in space chasing after their discoveries. The images used in Galaxy Zoo: Hubble are more detailed and beautiful than ever, and will allow us to look deeper into the history of our Universe and the whole Universe.

- [http://www.galaxyzoo.org](http://www.galaxyzoo.org)
What have we learned?

• How are the lives of galaxies connected with the history of the universe?
  – Many galaxies were formed when the universe was young and have aged along with the universe

• What are the three major types of galaxies?
  – Spiral, elliptical, and irregular galaxies
  – Spirals have both disk and spheroidal (bulge) 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
Star Formation Histories

Roughly speaking,

- **Initial Burst**: A sharp increase in star formation rate followed by a plateau. This results in an elliptical galaxy with a red core and envelope (old stellar population).

- **Constant Star Formation**: A steady rate of star formation over time. This leads to a spiral galaxy with a red bulge (old stellar population) and a blue disk (young stellar population).

(1 Gyr, 2 Gyr, 3 Gyr, 4 Gyr)
In the Hubble sequence, as you move from Sa to Sc type,

A. the spiral arms become more tightly wound.
B. the spiral arms do not change.
C. the spiral arms become less tightly wound.
D. the spiral arms disappear completely.
Quiz

Ellipticals are “gas poor” today because

A. they were formed with very little gas.

B. all the gas was removed in a merger with another galaxy.

C. all the gas was used up early on to form stars.

D. all the gas evaporated because of strong radiation.
Quiz

A galaxy that appears to be populated by mostly red stars likely

A. never had blue stars in the galaxy.

B. had blue stars that are not present anymore but were at one time long ago.

C. has been around long enough for the blue stars to have already evolved into red stars.

D. never contained enough gas to have blue stars develop.

E. has blue stars that are being blocked by dust.