The April Brooks Observatory sessions

Because of our poor weather this semester, additional observing sessions have been scheduled for ASTR 1010, beginning at 8:45 PM each evening:

• Sunday, April 13 through Wednesday, April 16, including this evening which will likely be held.

• Sunday, April 20 and Thursday, April 24 (newly scheduled)

Not required if you have already been to Brooks this semester & written a report.

If you attend this week, report due Wednesday, April 23.

If next week, report due at final exam (April 30).
As before, take elevator to 5th floor of this building, walk up to 6th floor. Bring your *blue* ticket with your name and my name (Nancy Morrison) written on it. Extra blue tickets are available.

**Quiz 6 is graded and available for pickup in back**

Homework 6 is due and will be collected shortly.

Planetarium and observing reports are also checked and available for pickup.

Next week Wednesday: course evaluation questionnaire
About the final exam

Wednesday, 30 April 2008, 7:30–9:30 PM, MH 1005

Comprehensive

Between 75 and 100 multiple-choice questions similar to tests

Counts 37.5% of grade (75 points out of 200)

Study suggestions

• Old tests: make sure you understand missed questions
• Homework, especially frequently missed questions
• Look for connections across segments of course
The Galaxy

A galaxy is a large grouping of up to a trillion stars that are bound together by their mutual gravitational attraction.

“The Galaxy” (capital G) refers to the one in which we live.

The Milky Way

- A dimly luminous, broad band of light encircling the sky and made of the light of thousands of stars too dim to be seen individually
- The Galaxy as seen from our point of view
- This name is also given to the Galaxy.
Contents

• Stars

• Star clusters, 2 types
  – Open clusters
    ∗ No particular shape
    ∗ Up to 1000 stars in a diameter of a few light years
– Globular clusters

- Spherical in shape
- 100,000 or more stars in a diameter of about 300 light years
- Oldest dated objects, age typically about 13 billion years

- Interstellar material
  - Very low-density material pervading nearly empty space between the stars
  - Gas
– Dust

* Small solid particles; like smoke

* Dims and reddens starlight by scattering or deflecting light from its path, short-wavelength light more than long-wavelength light

* Limits our ability to detect light from distant objects within the plane of the Galaxy

– Nebulae: denser concentrations or “clouds” some light years across; usually include both gas and dust
Structure of Galaxy: mapped out from studies of locations of thousands of stars and star clusters

- Within the Milky Way, young stars and ionization nebulae trace out arms

- As a group, globular clusters locate the center of the Galaxy at a distance of about 25,000 light years from us, beyond the constellation Sagittarius

But only a fraction of the Galaxy is observable to us in visible light; interstellar dust blocks out the rest.

Full-sky view of the Milky Way in infrared light
Rotation and mass of the Galaxy

- The Sun orbits the center of the Galaxy at a speed of about 150 miles per second. At that rate, it completes an orbit in 250 million years.

- From the speed and distance, the law of gravity says that the mass inside the Sun’s orbit is about 100 billion solar masses.
Center of the Galaxy

- At the precise center of the Galaxy is a radio source called Sagittarius A*.

- **Infrared pictures** show a large cluster of stars, each star orbiting the center. Over the course of a decade, their motions have been measured with sensitive equipment.

- One star is on a **15-year elliptical orbit** plunging in to a distance of only 17 light hours from the center.

- From its orbit, calculations show it is orbiting an object with a mass of about a million Suns.
• From the small size, the object Sagittarius A* must be a supermassive black hole.

• As we’ll see, massive black holes are often found in the centers of galaxies.
Galaxies

Spiral: similar to the one we live in

Galaxy face on

Location of Sun

100,000+ light years

25,000 light years

Galaxy edge on
Elliptical

- Elliptical in shape (round or oval)
- Little/no interstellar matter; just stars
- Come in all sizes: small ("dwarf"), large ("giant"), and in between

Irregular: a catchall category for galaxies that don’t fit into either the spiral or the elliptical classification

Galaxies’ distances are estimated by use of Cepheid variable stars in the galaxies as standard candles.
Among the Galaxy’s neighbors

- Spiral: the Andromeda Galaxy, the nearest spiral, at about 2 million light years distance
- Elliptical: 2 small satellites of the Andromeda Galaxy
- Irregular: the Small and the Large Magellanic Clouds, satellites of the Galaxy

Along with these and other neighbors, the Galaxy belongs to a group of about 50 galaxies (mostly small ones) called the Local Group.
Many galaxies are found in groups & clusters.

The most nearby cluster: the **Virgo Cluster** of galaxies, distance 50 million light years, diameter about 7 million light years.

Unlike stars in a galaxy, galaxies in a cluster are not very far apart, compared to their sizes.

Therefore, **collisions** between galaxies are routine. The collision slows the galaxies down, and after several close passages they merge, forming a single, larger galaxy, probably an **elliptical galaxy**.
Motions of galaxies: the Doppler Effect

Light wave from source at rest:

From source moving away from observer:
From source moving toward observer:

The amount of “stretching” or “shrinking” of the waves is proportional to the speed of the source.

Result: all the lines in the spectrum of a star appear at slightly shorter/longer wavelengths if the star is moving toward/away from us.
Redshifts of galaxies

Spectra of galaxies look like spectra of mixtures of different kinds of stars, and they show a standard pattern of spectral lines. Rough sketch:

![Rough sketch of spectral lines](image-url)
Except for galaxies in the Local Group, all galaxies have these lines shifted toward longer wavelengths, indicating that the galaxies are moving away from us.

The amount of shift toward longer wavelength is called the redshift.

The redshift is proportional to the radial velocity of the object.
Hubble’s Law of Redshifts (or, the Hubble Relation)

• The radial velocities of the lines in the spectra of galaxies are proportional to the galaxies’ distances from our galaxy.

• Distance twice as great implies radial velocity twice as great, etc.

• If you divide the radial velocity of a galaxy by its distance, you always get about the same number. This number is called the Hubble Constant.
Importance and implications of Hubble’s Law

• The galaxies move away from each other—not just from our galaxy.

• Distances between galaxies enlarge; space expands; the universe is expanding.

• Actually, clusters of galaxies do not expand and, of course, galaxies themselves do not expand. Therefore, it is more accurate to say that the clusters of galaxies move apart.
Fig. 2 — The space distribution of the associations, O, clusters, , and H II regions, x, with supergiant members. H II regions with kinematic distances are designated by Δ and the arrow indicates the probable correction to the distance due to noncircular motions.