ASTR 1010–004: significant dates

Wednesday, Nov. 28: Quiz 7; Homework 7 distributed

Wednesday, Dec. 5: Homework 7 due

Tuesday, Dec. 11: extra office hours, 4 to 7 PM

Wednesday, Dec. 12: final exam 7:30 PM, here

Additional Brooks Observatory opportunities

Quiz 7 coverage

Nov. 19: life stages of a massive star; supernova explosions; origin of the elements; evolution of binary stars. Stellar remnants: white dwarfs; neutron stars; black holes (introduction)

Nov. 26 (today): black holes (continued); the Galaxy, galaxies, including active galaxies and quasars (continued Wed. if not finished today)
Black Holes (continued)

Definitions

*Event horizon* An imaginary sphere, centered on a black hole, where the escape speed just equals the speed of light

*Black hole* An object at whose surface the escape speed exceeds the speed of light

- From anywhere outside the event horizon, light can escape from the pull of the black hole.

- Inside it, light cannot escape. Neither can anything else.
A 3-solar-mass black hole “seen” from 1 AU away

- Emits no light

- Same gravitational pull as a 3-solar mass star would have at the same distance, so it is safe to orbit the black hole.

- The event horizon is an intangible sphere 12 miles across.
Observe black holes from matter falling into them, as with neutron stars.

In a close binary star, the transferred matter forms a disk around the black hole.

The disk is strongly heated by friction within itself and emits X-rays.

Material at the inner edge of the disk falls in through the event horizon and disappears.

Summary: Sun/white dwarf/neutron star/ black hole comparison
**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 (some with planets)
• Star clusters, 2 types
  – Open clusters
    • No particular shape
    • Up to 1000 stars in a diameter of a few light years

Should also include brown dwarfs, free-floating planets
– 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

∗ As a group, locate the center of the Galaxy

• 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

But still only a fraction of the Galaxy is observable to us; interstellar dust blocks out the rest.
Galaxies

**Spiral:** similar to the one we live in

Galaxy face on

Galaxy edge on

100,000+ light years

25,000 light years

Location of Sun
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 certain 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
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:
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.
us

them
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.
neutron star, 1 solar mass (diameter about 10 miles)

black hole, 1 solar mass (hypothetical, diameter about 4 miles)