Quiz 4 Review, Astronomy 1144

1 Supernovae

- Which stars will go supernova at the end of their lives?
  1. Those which begin their lives more massive than about 8 solar masses.
  2. Also, white dwarfs which are accreting material from a companion star may also go supernova.
- What types of supernovae are there? How are they differentiated?
  1. There are two main types of supernova, with subclasses: Type I and II.
  2. Type I supernovae do not have hydrogen lines in their spectra, while Type II's do.
- What forms Type II supernovae? Type I?
  1. Type II supernovae are all formed by the massive stars exploding following the collapse of their iron cores.
  2. Type I's are formed from exploding white dwarfs.
- What do supernovae leave behind?
  1. Type II's leave behind neutron stars or black holes: the remnant of the collapsed core of the star.
  2. Type I's involve the total destruction of the white dwarf, and thus leave no central remnant behind.
- What are neutron stars? Pulsars?
  1. Neutron stars are similar to white dwarfs in that they are bodies of degenerate matter left over after the death of a star. Unlike white dwarfs, neutron stars form in supernovae.
  2. Neutron stars, however, are supported by neutron degeneracy pressure, not electron degeneracy pressure.
  3. They are also much smaller than white dwarfs, no more than about 10 km across, roughly the size of Manhattan.
  4. Pulsars are very rapidly spinning neutron stars which emit beams of radiation from their magnetic poles. If the magnetic field axis is aimed towards us, we see pulses of radiation as the beam sweeps over us.

2 General Relativity

- What is the main statement of general relativity, and why do we need GR?
  1. GR says that gravity is not a force; instead, it is simply the result of matter curving spacetime.
  2. GR is needed because Newtonian gravity does not explain everything we see; instead, it breaks down near large masses and at speeds close to the speed of light.

- What are the defining characteristics of a black hole?
  1. A black hole is something so dense that not even light can escape from it if it gets too close.
  2. A black hole may be completely described with only its mass, electric charge, and spin.
- What is the event horizon? The singularity?
  1. The event horizon is the point of no return. Beyond it, nothing can escape, not even light.
  2. It is more rigorously defined as the point at which the escape velocity of the black hole is equal to the speed of light, c.
  3. The singularity is the point at the very center of the black hole. All the mass that makes up the hole is compressed into a single point at the center, according to GR.
- What is the Schwarzschild radius?
  1. It is the radius of the event horizon. If an object is compressed to a size smaller than its Schwarzschild radius, it will inevitably collapse to form a black hole.
  2. The Schwarzschild radius for the Sun is about 3 km. The Earth's is roughly 1 cm.
- What is gravitational lensing?
  1. Light follows the curvature of spacetime, so it bends as it passes nearby massive objects. This is gravitational lensing: gravity bending light.

3 The Cosmic Distance Ladder

- What are some of the rungs on the cosmic distance ladder?
  1. Trigonometric parallax.
  2. Spectroscopic parallax.
  3. Cepheid and RR Lyrae variables.
  4. Tully-Fisher Relation.
  5. Type Ia supernovae.
- How do the above techniques work? What distance ranges do they cover?
  1. Trigonometric parallax involves measuring the annual change in position of nearby stars relative to background ones over the course of the year. It is accurate for only the closest objects - no more than 1000 pc away.
  2. Spectroscopic parallax works by measuring the apparent brightness, spectral type, and luminosity class of a star, giving an estimate of its luminosity. That then gives a distance estimate. This is good out to about 50 kpc.
  3. Cepheids and RR Lyraes are variable stars whose pulsation periods are directly tied to their luminosities. Cepheids are massive stars, while RR Lyraes are low-mass stars. Both have evolved off the main sequence. This method is good out to 30-40 Mpc, beyond which the individual stars cannot be resolved.
  4. The Tully-Fisher relation relates how quickly a spiral galaxy is spinning to its luminosity. More massive galaxies rotate more quickly and have more stars, so they are more luminous than less massive galaxies. By looking at a galaxy's rotation curve, you can estimate its mass and thus luminosity, giving a distance. Good out to a few hundred Mpc, but fairly imprecise.

5. Type Ia supernovae have brightnesses which are strongly tied to how quickly they fade away, so they function as "standard candles." They are visible out to several hundred Mpc, and can give relatively precise distances, but are rare for any one galaxy.

- How is the distance ladder used?
  1. The distance ladder is used to set the physical scale of the universe.
  2. By using Hubble's Law relating redshift to recessional velocity and distance, and by redshifts to objects of known distance, we can measure changes in the expansion of the universe.

4 Galactic Dynamics and Classification

- What are the main constituents of the Milky Way galaxy?
  1. The Milky Way has a rotating disk of stars, gas, and dust, a central bulge of old stars, a halo of dark matter and old stars, and a supermassive black hole at its center.
- Can stars account for all of the mass of the Milky Way? How do we know?
  1. No, stars cannot account for all of the Milky Way's mass.
  2. The rotation curve (how fast stars orbit at different distances from the center) is flat as you go outward from the center of the galaxy, even far past where the stars mostly stop.
  3. Objects out there in the halo orbit at roughly the same speed as the Sun; if the mass were concentrated with the stars, we would expect the stars further out to orbit much more slowly than they do.
- How can we explain the discrepancy between the visible stars and the flat galactic rotation curves?
  1. The best solution astronomers have come up with is dark matter.
  2. This is extra matter that interacts very weakly with baryons and photons.
  3. 90% of the matter in the universe is dark matter. We still do not know what exactly it is.
- What are the various Populations of stars? How are they differentiated?
  1. Stars are classified into Populations by the amount of metals (in astronomy, elements heavier than hydrogen and helium) they contain.
  2. Population I stars are relatively young and metal-rich. In spiral galaxies, they tend to be found in the arms and disk. The Sun is an intermediate Population I star.
  3. Population II stars are old, metal-poor stars, and are not found in the disk. Globular clusters and the central bulge are made up of Population II stars; the galactic halo is also largely Population II stars.
  4. Population III stars are very metal-poor stars which formed in the very early universe, and have virtually no metals. None have yet been observed.
- What is at the center of most galaxies?
  1. Most galaxies have a supermassive black hole at their centers.
  2. The Milky Way is no different. Sagittarius A is a radio source which marks the center of the Milky Way, and is thought to come from such a supermassive black hole.
- What are some different types of galaxies? What are some of their characteristics?

1. Ellipticals: No disk, dust, or spiral arms. Large elliptical/spherical agglomerations of stars. Further classified by how elongated they appear: E0's are nearly spherical, while E9's are extremely elongated/cigar- or football-shaped.
2. Spirals: Disk galaxies with a central spherical bulge. Arms are often blue and dusty from the formation of new, young stars. Further classified based on the size/prominence of the bulge and how tightly the arms are wound. Sa's have large bulges and more tightly wound/less prominent arms, while Sc's have small bulges and prominent/loosely wound arms. The Milky Way is a spiral galaxy.
3. Barred Spirals: Similar to spirals, except that their bulges are elongated into football-shaped bars. Finer classification is the same, using SBa, SBb, etc. instead of Sa, etc.
4. Irregulars: Galaxies with no regular, defined shape. Often very small satellite galaxies such as the Magellanic clouds.

5 Active Galactic Nuclei (AGN)

- What is an active galactic nucleus (AGN)?
  1. It is an extremely bright and compact nucleus with non-stellar spectra (i.e., it does not look like it is made of stars).
  2. They can sometimes outshine their entire host galaxy. In fact, quasars, a type of AGN, are the most luminous objects in the universe.
- What is the power source for an AGN?
  1. All AGN are powered by the accretion of matter onto the central supermassive black hole of the galaxy.
  2. That is, as matter falls onto the black hole, it forms a disk and heats up greatly, causing it to shine very brightly.
  3. Some of the infalling material may be ejected along two finely narrowly-focused jets from the poles of the black hole.
- What are some types of AGN? How are they classified?
  1. AGN types include Seyfert galaxies (Type I and II), radio galaxies, quasars, and blazars.
  2. It is thought that which type of AGN is seen depends on the viewing angle.
  3. Looking straight down the jet produces a blazar, while quasars and Seyferts are seen at more of an angle.
  4. The difference between Seyferts and quasars is mainly their luminosity: A Seyfert nucleus may be roughly as bright as the host galaxy, while a quasar may outshine it by a factor of 100 or more.
  5. Seyferts are additionally only found in spiral galaxies.
- Is the Milky Way's nucleus considered active?
  1. No, the Milky Way does not have an AGN.