**Galaxies and the Foundations of Modern Cosmology**

20.1 Multiple-Choice Questions

1) Based on counting the number of galaxies in a small patch of the sky and multiplying by the number of such patches needed to cover the entire sky, the total number of galaxies in the observable universe is estimated to be approximately

A) 100 million.

B) 1 billion.

C) 10 billion.

D) 100 billion.

E) 1 trillion.

Answer: D

2) Suppose that we look at a photograph of many galaxies. Assuming that all galaxies formed at about the same time, which galaxy in the picture is the youngest?

A) the one that is reddest in color

B) the one that is bluest in color

C) the one that is farthest away

D) the one that is closest to us

E) the one that appears smallest in size

Answer: C

3) Which of the following types of galaxies are most spherical in shape?

A) spirals

B) ellipticals

C) lenticulars

D) irregulars

Answer: B

4) Which of the following types of galaxies are reddest in color?

A) spirals

B) ellipticals

C) lenticulars

D) irregulars

Answer: B

5) Which of the following statements about galaxies is true?

A) Small galaxies outnumber large galaxies and produce most of the light in the universe.

B) Small galaxies outnumber large galaxies but large galaxies produce most of the light in the universe.

C) There is an approximately equal number of small and large galaxies in the universe and together they each contribute an equal amount of light.

D) Most galaxies in the universe are about the same size as the Milky Way.

E) Galaxies come in a wide variety of shapes and sizes but are all very blue in color.

Answer: B

6) Which types of galaxies have a clearly defined spheroidal component?

A) spirals only

B) ellipticals only

C) lenticulars only

D) irregulars only

E) all but irregulars

Answer: E

7) Which types of galaxies have a clearly defined disk component?

A) spirals only

B) ellipticals only

C) lenticulars only

D) irregulars only

E) spirals and lenticulars

Answer: E

8) Compared to spiral galaxies, elliptical galaxies are

A) redder and rounder.

B) redder and flattened.

C) bluer and rounder.

D) bluer and flattened.

E) always much smaller.

Answer: A

9) The disk component of a spiral galaxy includes which of the following parts?

A) halo

B) bulge

C) spiral arms

D) globular clusters

E) all of the above

Answer: C

10) How does a *lenticular galaxy* differ from a normal spiral galaxy?

A) It has no bulge.

B) It has an elongated bulge resembling a bar more than a sphere.

C) It is flatter in shape.

D) It has no gas or dust.

E) It has no spiral arms.

Answer: E

11) What is the major difference between an elliptical galaxy and a spiral galaxy?

A) A spiral galaxy contains mostly younger stars.

B) A spiral galaxy has a spherical halo.

C) An elliptical galaxy lacks a disk component.

D) Elliptical galaxies are not as big as spiral galaxies.

E) There are no *dwarf spiral galaxies*, but there are *dwarf ellipticals*.

Answer: C

12) Most large galaxies in the universe are

A) elliptical.

B) spiral or lenticular.

C) irregular.

D) abnormal.

Answer: B

13) Which of the following types of galaxies are most commonly found in large clusters?

A) spirals

B) ellipticals

C) lenticulars

D) irregulars

Answer: B

14) Approximately how many stars does a *dwarf elliptical galaxy* have?

A) 1 trillion

B) 100 billion

C) 10 billion

D) less than a billion

E) less than a million

Answer: D

15) Which of the following is true about irregular galaxies?

A) They are composed solely of old stars.

B) They generally have significant bulge populations.

C) They were more common when the universe was younger.

D) They have reddish colors.

E) They have well defined spiral arms.

Answer: C

16) Why are Cepheid variables important?

A) Cepheid variables are stars that vary in brightness because they harbor a black hole.

B) Cepheids are pulsating variable stars, and their pulsation periods are directly related to their true luminosities. Hence, we can use Cepheids as "standard candles" for distance measurements.

C) Cepheids are a type of young galaxy that helps us understand how galaxies form.

D) Cepheids are supermassive stars that are on the verge of becoming supernovae and therefore allow us to choose candidates to watch if we hope to observe a supernova in the near future.

Answer: B

17) What is a *standard candle*?

A) an object for which we are likely to know the true luminosity

B) an object for which we can easily measure the apparent brightness

C) a class of objects in astronomy that all have exactly the same luminosity

D) any star for which we know the exact apparent brightness

E) a long, tapered candle that lights easily

Answer: A

18) Why is the Hyades Cluster important for building up a catalog of the true luminosities of main-sequence stars?

A) It is an extremely bright cluster.

B) It is close enough to us that the distance to the cluster stars can be found by stellar parallax.

C) It is an old globular cluster that has been around our galaxy for several billion years.

D) We have brightness measurements for the stars in the cluster over many decades, so we know how the stars vary in brightness.

E) It contains many Cepheid variables.

Answer: B

19) How did Edwin Hubble measure the distance to the Andromeda Galaxy?

A) He measured its parallax.

B) He used main-sequence fitting.

C) He applied the period-luminosity relation to Cepheid variables.

D) He deduced it from its redshift.

E) He used white dwarf supernovae.

Answer: C

20) How was Edwin Hubble able to use his discovery of a Cepheid in Andromeda to prove that the "spiral nebulae" were actually entire galaxies?

A) There are no Cepheids in the Milky Way, so his discovery proved that it had to be in another galaxy.

B) He measured the stellar parallax of the Cepheid in Andromeda, was able to determine the distance to it, and showed that it was far outside the Milky Way Galaxy.

C) He used main-sequence fitting to determine the distance to Andromeda and show that it was far outside the Milky Way Galaxy.

D) From the period-luminosity relation for Cepheids, he was able to determine the distance to Andromeda and show that it was far outside the Milky Way Galaxy.

E) Since a Cepheid is a type of luminous galaxy, when he found it in Andromeda he was able to prove that Andromeda was a separate galaxy from the Milky Way.

Answer: D

21) What two quantities did Edwin Hubble plot against each other to discover the expansion of the Universe?

A) velocity and distance

B) luminosity and distance

C) velocity and temperature

D) luminosity and temperature

E) age and distance

Answer: A

22) What is *Hubble's law*?

A) The longer the time period between peaks in brightness, the greater the luminosity of the Cepheid variable star.

B) The recession velocity of a galaxy is directly proportional to its distance from us.

C) The recession velocity of a galaxy is inversely proportional to its distance from us.

D) The faster a spiral galaxy's rotation speed, the more luminous it is.

E) The faster a spiral galaxy's rotation speed, the less luminous it is.

Answer: B

23) Which of the following is a consequence of Hubble's Law?

A) the Big Bang

B) all galaxies are moving away from us equally fast

C) the more distant a galaxy is from us, the faster it moves away from us

D) the closer a galaxy is to us, the faster it moves away from us

E) more distant galaxies appear younger

Answer: C

24) What is the primary practical difficulty that limits the use of Hubble's law for measuring distances?

A) Redshifts of galaxies are difficult to measure.

B) The recession velocities of distant galaxies are so great that they are hard to measure.

C) We do not know Hubble's constant very accurately yet.

D) Hubble's law is only useful theoretically; it is difficult to use in practice.

E) The motion of Earth relative to the Milky Way is difficult to account for.

Answer: C

25) White-dwarf supernovae are good standard candles for distance measurements for all the following reasons except which?

A) All white-dwarf supernovae involve the explosion of stars of nearly the same mass.

B) White-dwarf supernovae are so bright that they can be detected even in very distant galaxies.

C) White-dwarf supernovae are common enough that we detect several every year.

D) White-dwarf supernovae occur only among young and extremely bright stars.

E) All white-dwarf supernovae have similar light curves, which makes them easy to distinguish from massive-star supernovae.

Answer: D

26) What makes *white-dwarf supernovae* good standard candles?

A) They are very bright, so they can be used to determine the distances to galaxies billions of light-years away.

B) They should all have approximately the same luminosity.

C) They occur so frequently that we can use them to measure the distances to virtually all galaxies.

D) We have had several occur close to us in the Milky Way, so we have been able to determine their luminosities very accurately.

E) both A and B

Answer: E

27) What is the most accurate way to determine the distance to a nearby star?

A) radar ranging

B) stellar parallax

C) main-sequence fitting

D) using Cepheid variables

E) Hubble's law

Answer: B

28) What is the most accurate way to determine the distance to a nearby galaxy?

A) radar ranging

B) stellar parallax

C) using Cepheid variables

D) main sequence fitting

E) Hubble's law

Answer: C

29) What is the most accurate way to determine the distance to a very distant irregular galaxy?

A) main-sequence fitting

B) using Cepheid variables

C) using a white-dwarf supernova as a standard candle

D) main sequence fitting

E) Hubble's law

Answer: C

30) Which of the following sequences lists the methods for determining distance in the correct order from nearest to farthest?

A) main-sequence fitting, parallax, Cepheid variables, Hubble's law

B) parallax, main-sequence fitting, Cepheid variables, Hubble's law

C) parallax, main-sequence fitting, Hubble's law, Cepheid variables

D) parallax, main-sequence fitting, white-dwarf supernovae, Hubble's law

E) main-sequence fitting, parallax, Hubble's law, white-dwarf supernovae

Answer: B

31) Dr. X believes that the Hubble constant is *H0* = 55 km/s/Mpc. Dr. Y believes it is *H0* = 80 km/s/Mpc. Which statement below automatically follows?

A) Dr. X believes that the universe is expanding, but Dr. Y does not.

B) Dr. X believes that the Andromeda Galaxy (a member of our Local Group) is moving away from us at a slower speed than Dr. Y believes.

C) Dr. X believes that the universe is older than Dr. Y believes.

D) Dr. X believes that the universe will someday stop expanding, while Dr. Y believes it will expand forever.

E) Dr. X believes that the universe has a much higher density than Dr. Y believes.

Answer: C

32) Dr. Smith believes that the Hubble constant is *H0* = 70 km/s/Mpc. Dr. Jones believes it is *H0* = 50 km/s/Mpc. Which statement below automatically follows?

A) Dr. Smith believes that the universe is expanding, but Dr. Jones does not.

B) Dr. Smith believes that the Andromeda Galaxy (a member of our Local Group) is moving away from us at a faster speed than Dr. Jones believes.

C) Dr. Smith believes that the universe is older than Dr. Jones believes.

D) Dr. Smith believes that the universe is younger than Dr. Jones believes.

E) Dr. Smith believes that the universe will someday stop expanding, while Dr. Jones believes it will expand forever.

Answer: D

33) Recall that *Hubble's law* is written *v = H0d*, where *v* is the recession velocity of a galaxy located a distance *d* away from us, and *H0* is *Hubble's constant*. Suppose *H0* = 65 km/s/Mpc. How fast would a galaxy located 500 megaparsecs distant be receding from us?

A) 65 km/s

B) 65 Mpc/s

C) 32,500 km/s

D) 9 km/s

E) 0.65 times the speed of light

Answer: C

34) Hubble's "constant" is constant in

A) time.

B) space.

C) space and time.

D) our Galaxy but different in others.

Answer: B

35) Based on current estimates of the value of Hubble's constant, how old is the universe?

A) between 4 and 6 billion years old

B) between 8 and 12 billion years old

C) between 12 and 16 billion years old

D) between 16 and 20 billion years old

E) between 20 and 40 billion years old

Answer: C

36) Why can't we see past the *cosmological horizon*?

A) The universe extends only to this horizon.

B) Beyond the cosmological horizon, we are looking back to a time before the universe had formed.

C) We do not have telescopes big enough.

D) We do not have sensitive enough detectors.

E) The cosmological horizon is infinitely far away, and we can't see to infinity.

Answer: B

37) What does the equivalent of an H-R diagram for galaxies, plotting luminosity versus color, show?

A) galaxies fill the diagram showing that there is no correlation between luminosity and color

B) two clumps, one blue with relatively low luminosity, one red with relatively high luminosity, and a valley in between with few galaxies

C) a continuum from faint, blue galaxies to bright, red galaxies

D) a continuum from faint, red galaxies to bright, blue galaxies

E) A main sequence, just as for stars

Answer: B

20.2 True/False Questions

1) Although it is difficult to tell from our vantage point inside the galaxy, astronomers suspect that the Milky Way is a barred spiral.

Answer: TRUE

2) Spiral galaxies have more gas, dust, and younger stars than elliptical galaxies do.

Answer: TRUE

3) Stars are continually forming in the halo of our Galaxy today.

Answer: FALSE

4) A lenticular galaxy is another name for an elongated elliptical galaxy.

Answer: FALSE

5) There are more large spiral galaxies than there are large elliptical galaxies.

Answer: TRUE

6) Elliptical galaxies are more likely to be found in clusters than are spiral galaxies.

Answer: TRUE

7) Massive-star supernovae and white-dwarf supernovae work equally well as standard candles for measuring cosmic distances.

Answer: FALSE

8) The larger the value of Hubble's constant, the more rapid the expansion of the universe and hence the younger the universe.

Answer: TRUE

20.3 Short Answer Questions

1) Explain how we estimate that there are about 50-100 billion galaxies in the observable universe.

Answer: Obviously it's impossible to count so many galaxies one by one, but by observing a small part in detail, we can extrapolate to get the total number. As an example, the Hubble deep field shows thousands of galaxies in a very small angular area of the sky (about equal to the size of a grain of sand held at arm's length). Multiplying the number of galaxies by the ratio of the angular area of the entire sky to the angular area of the deep field then gives an estimate of the total number of galaxies in the observable universe.

2) Summarize the links in the distance chain that allow us to estimate distances to the farthest reaches of the universe.

Answer: We can determine the distance to solar system objects through radar ranging. This gives us an accurate distance to the Sun so that we can use stellar parallax to measure the distances to the nearest stars. The Hyades is an open cluster whose stars are near enough to us that their distances can be measured with stellar parallax. This gives us a cluster of stars that we can plot on an H-R diagram to determine the luminosity of the main sequence. For more distant clusters, we can compare their main sequence to this fit and measure their distance by the method of main-sequence fitting. The distances to Cepheid variables in clusters can be determined from main-sequence fitting. Since there is a period-luminosity relationship for Cepheids, we can measure the distances to other Cepheids by just measuring the time period between peaks of brightness. Cepheids are bright enough to be observed in galaxies other than the Milky Way. Therefore, they serve as a bridge between us and standard candles in other galaxies. Once we determine the distance to another galaxy for which we have observed a white-dwarf supernova, we then can calibrate the average luminosity of white-dwarf supernovae. White-dwarf supernovae and Cepheids get us far enough away from the Milky Way that we then can calibrate Hubble's law by determining the Hubble constant. Once we know the Hubble constant, we will be able to determine a galaxy's distance from its redshift.

3) List at least three qualities that would tend to make a type of astronomical object useful as a standard candle.

Answer: Answers will vary, but some of the key properties of good standard candles include little statistical scatter in brightness; high luminosity, so they can be seen at a great distance; and relative commonness, so they can be found in many objects.

4) Explain why we observe distant galaxies to be moving away from us and therefore believe that the universe is expanding, but we don't see individual galaxies or clusters expanding.

Answer: The pull of gravity works to slow the expansion rate of the universe. Therefore, in dense regions such as galaxies and clusters of galaxies, gravity is able to overcome the expansion and keep these objects from expanding. However, on larger scales, where the average density is lower, gravity does not have as strong an effect, and therefore the expansion continues between clusters of galaxies.

5) Briefly explain why we think white-dwarf supernovae are useful for measuring cosmic distances.

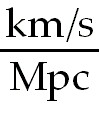
Answer: They all come from explosions of white dwarfs that reach the white-dwarf limit, so we expect them all to have the same luminosity; observations of white-dwarf supernovae for which we can measure distance independently confirm that they all have the same luminosity. Since we can assume we know their luminosity, we can use their apparent brightnesses to determine distance from the luminosity-distance formula.

6) How does the age of the universe depend on Hubble's constant, and why?

Answer: The larger the value of Hubble's constant, the younger is the universe. This is because a larger value for Hubble's constant means the universe is expanding faster, which means it took less time to reach its current size.

7) Recall that *Hubble's law* is written *v = H0d*, where *v* is the recession velocity of a galaxy located a distance *d* away from us, and *H0* is Hubble's constant. Suppose *H0* = 55 km/s/Mpc. How fast would a galaxy located 500 megaparsecs distant be receding from us? Show all work clearly, and state your final answer with a complete sentence. Give the speed in units of kilometers per second and as a percentage of the speed of light.

Answer:

*v = H0d =* (55 (500 Mpc)

*=* 27,500 

*=* 0.09*c*

The galaxy is receding from us at 27,500 km/s, or 9 percent of the speed of light.

8) *Process of Science*: Describe how scientists measure the distances to galaxies, starting with how they measure the distances of the nearest stars. Be sure to include enough detail so that someone who does not know the jargon of astronomy can still understand your explanation.

Answer: They use parallax to get the distance to nearby stars and then use standard candles to measure farther distances.

9) *Process of Science*: Most galaxies do not obey Hubble's Law perfectly. Why do we not take this as evidence that Hubble's law (and the theory of the expanding universe) is incorrect?

Answer: Hubble's law describes motions due only to expansion of the universe. In reality we expect (and observe) that actual galaxies experience gravitational effects from other objects and galaxies they encounter, making their motions slightly different from the pure Hubble's law prediction.

10) *Process of Science:* Give examples of how we build upon our knowledge of stars to measure distances to the edge of the Universe?

Answer: We use established theories for stellar evolution such as main sequence fitting, Cepheid variables, and the Chandrasekhar limit for white dwarf masses as critical steps on the distance ladder.

11) *Process of Science:* How we can test that a so-called "standard candle" is indeed standard?

Answer: We have to measure both the absolute luminosity of many examples of a standard candle through observations of their apparent brightness and independent measures of their distance. Only once absolute luminosities are fully calibrated in this way, can we then reverse the process and use their apparent brightness to infer distances.

20.4 Mastering Astronomy Reading Quiz

1) Based on the number of galaxies visible in the Hubble Deep Field (Figure 20.1 in your textbook), the estimated number of galaxies in our observable universe is

A) about 50,000.

B) about 100 million.

C) about 100 billion.

D) an infinite number.

Answer: C

2) Which of the following is *not* one of the three major categories of galaxies?

A) elliptical galaxies

B) globular galaxies

C) spiral galaxies

D) irregular galaxies

Answer: B

3) Galaxies with disks but no evident spiral arms are called

A) irregular galaxies.

B) lenticular galaxies.

C) barred spiral galaxies.

D) spheroidal components.

Answer: B

4) Which of the following best describes the status of the Milky Way in our Local Group of galaxies?

A) It is one of the two largest galaxies in the group.

B) It is one of about a dozen large spiral galaxies in the group.

C) It is by far the largest galaxy in the group.

D) It is quite average among the galaxies in the group.

Answer: A

5) A *standard* *candle* is

A) a 7-cm-long wax candle.

B) another name for a main-sequence star.

C) another name for a barred-spiral galaxy.

D) a light source of known luminosity.

Answer: D

6) What is *main-sequence fitting*?

A) It is a method for determining the distance to a star cluster by assuming that its main sequence should line up with the main sequence on a standard H-R diagram.

B) It is a method for determining the age of a star cluster.

C) It is a way of forcing stars to fit into a standard main sequence, even when they have some unusual characteristics.

D) It is the way we construct an H-R diagram by plotting the surface temperatures and luminosities of stars.

Answer: A

7) What is a *Cepheid variable*?

A) It is a bright source of variable X-ray emission, thought to harbor a supermassive black hole.

B) It is a type of very luminous star that makes an excellent standard candle.

C) It is a main-sequence star of spectral type B5.

D) It is a type of galaxy that varies in its light output.

Answer: B

8) What two observable properties of a Cepheid variable are directly related to one another?

A) the period between its peaks of brightness and its distance

B) its luminosity and its mass

C) the period between its peaks of brightness and its luminosity

D) its mass and its distance

Answer: C

9) What does *Hubble's law* tell us?

A) The faster a spiral galaxy's rotation speed, the more luminous it is.

B) The longer the period of a Cepheid variable, the greater its luminosity.

C) For every force, there is an equal and opposite reaction force.

D) The more distant a galaxy, the faster it is moving away from us.

Answer: D

10) Given that white dwarf supernovae are such good standard candles, why don't we use them to measure the distance to *all* galaxies?

A) They are rare events, so we have observed them in only a tiny fraction of all galaxies.

B) We cannot see them beyond a distance of about 100 million light-years.

C) They can occur only in spiral galaxies, not elliptical galaxies.

D) We would, but we don't have enough telescopes.

Answer: A

11) Overall, what is our most accurate technique for measuring the distance to a nearby star?

A) radar ranging

B) stellar parallax

C) Hubble's law

D) main-sequence fitting

Answer: B

12) When we use an analogy that represents the expanding universe with the surface of an expanding balloon, what does the *inside* of the balloon represent?

A) It represents the center of the universe.

B) It represents the entire universe.

C) It represents regions of the universe beyond the Milky Way Galaxy.

D) The inside of the balloon does not represent any part of our universe.

Answer: D

13) If we say that a galaxy has a *lookback time* of 1 billion years, we mean that

A) its light traveled through space for 1 billion years to reach us.

B) is now 1 billion light-years away.

C) it was 1 billion light-years away when the light left the galaxy.

D) it is 400 million years old.

Answer: A

14) *Cosmological redshift* is the result of

A) the high speeds at which galaxies move within clusters.

B) the expansion of the universe.

C) very old, red stars in distant galaxies.

D) supermassive black holes.

Answer: B

15) Although the entire universe may be much larger than our observable universe, we can see only within our observable universe. The "boundary" of our observable universe is called

A) the cosmological horizon.

B) the Big Bang.

C) the lookback time.

D) the singularity.

Answer: A

16) Current estimates place the age of the universe at about

A) 10 billion years.

B) 10 million years.

C) 14 billion years.

D) 4 billion years.

Answer: C

17) You observe the peak brightnesses of two *white dwarf supernovae*. Supernova A is only 1/4 as bright as Supernova B. What can you say about their relative distances?

A) Supernova A is twice as far away as Supernova B.

B) Supernova A is 4 times as far away as Supernova B.

C) Supernova B is 4 times as far away as Supernova A.

D) Supernova B is twice as far away as Supernova A.

E) We can't say anything about their relative distances because we do not have enough information.

Answer: A

18) The fact that the universe is expanding means that space itself is growing within

A) the Milky Way.

B) clusters of galaxies.

C) the observable universe.

D) the Local Group.

Answer: C

19) Spectral lines from Galaxy B are redshifted from their rest wavelengths twice as much as the spectral lines from Galaxy B. According to Hubble's law, what can you say about their approximate relative distances?

A) Galaxy A is twice as far as Galaxy B.

B) Galaxy B is four times as far as Galaxy A.

C) Galaxy A is four times as far as Galaxy B.

D) Galaxy B is twice as far as Galaxy A.

E) Not enough information to say—you need to know Hubble's constant to answer this question.

Answer: D

20.5 Mastering Astronomy Concept Quiz

1) In a photo like the Hubble Deep Field (Figure 20.1 in your textbook), we see galaxies in many different stages of their lives. In general, which galaxies are seen in the *earliest* (youngest) stages of their lives?

A) the galaxies that are farthest away

B) the galaxies that have the most hot, young O and B stars

C) the galaxies that are the reddest in color

D) the galaxies that are nearest to us

Answer: A

2) Which of the following statements about types of galaxies is *not* true?

A) Spiral galaxies have younger stars than elliptical galaxies.

B) Among the large galaxies in the universe *outside* of clusters, most are spiral.

C) Large elliptical galaxies are more common in clusters of galaxies than they are outside of clusters.

D) Elliptical galaxies are bluer and contain more dust than spiral galaxies.

Answer: D

3) The most basic difference between elliptical galaxies and spiral galaxies is that

A) elliptical galaxies lack anything resembling the halo of a spiral galaxy.

B) elliptical galaxies have a spheroidal component (of stars distributed spherically about the galactic center), and spiral galaxies do not.

C) elliptical galaxies lack anything resembling the disk of a spiral galaxy.

D) elliptical galaxies are very old and spiral galaxies are very young.

Answer: C

4) Hubble's galaxy classification diagram (the "tuning fork")

A) explains active galactic nuclei.

B) shows how galaxies evolve from one form to another.

C) suggests the existence of black holes.

D) relates galaxies according to their shapes, but not according to any evolutionary status.

Answer: D

5) Using the technique of *main-sequence fitting* to determine the distance to a star cluster requires that

A) we have telescopes powerful enough to allow us to identify the spectral types of main-sequence stars of many masses in the cluster.

B) the cluster be near enough for us to measure the parallax of its stars.

C) we use ultraviolet and X-ray telescopes.

D) we have a well-calibrated period-luminosity relation for Cepheid variable stars.

Answer: A

6) Suppose that we suddenly discovered that all these years we'd been wrong about the distance from Earth to the Sun, and it is actually 10% greater than we'd thought. How would that affect our estimate of the distance to the Andromeda Galaxy?

A) It would not have any effect on our estimate of the distance to the Andromeda Galaxy.

B) It would mean the distance to the Andromeda Galaxy is also 10% greater than we thought.

C) It would mean the distance to the Andromeda Galaxy is 10% less than we thought.

D) It would mean that all the objects we've assumed are standard candles really are not good standard candles, and therefore that we have no idea of the true distance to the Andromeda Galaxy.

Answer: B

7) Suppose we observe a Cepheid variable in a distant galaxy. The Cepheid brightens and dims with a regular period of about 10 days. What can we learn from this observation?

A) It will allow us to calculate the rotation rate of the galaxy.

B) It will allow us to determine the mass of the galaxy.

C) We can learn the distance to the galaxy.

D) Under the rules of the International Astronomical Union, we will be entitled to naming rights for the galaxy.

Answer: C

8) In 1924, Edwin Hubble proved that the Andromeda Galaxy lay far beyond the bounds of the Milky Way, thus putting to rest the idea that it might have been a cloud within our own galaxy. How was he able to prove this?

A) He proved this by observing individual Cepheid variable stars in Andromeda and applying the period-luminosity relation.

B) He was able to measure the parallax of the Andromeda Galaxy.

C) He found that the universe is expanding, and therefore concluded that Andromeda must lie outside our own galaxy.

D) He was the first person ever to look through a telescope at the object we now call the Andromeda Galaxy.

Answer: A

9) Suppose that Hubble's constant were 20 kilometers per second per million light-years. How fast would we expect a galaxy 100 million light-years away to be moving? (Assume the motion is due only to Hubble's law.)

A) away from us at 200 km/s

B) toward us at 2,000 km/s

C) away from us at 2,000 km/s

D) away from us at 20,000 km/s

Answer: C

10) Does Hubble's law work well for galaxies in the Local Group? Why or why not?

A) No, because Hubble did not know the Local Group existed when he discovered his law.

B) No, because galaxies in the Local Group are gravitationally bound together.

C) No, because we do not know the precise value of Hubble's constant.

D) Yes, it works so well that we have never detected any measurable deviations from its predictions.

Answer: B

11) Why are white dwarf supernovae more useful than massive star supernovae for measuring cosmic distances?

A) We can see only white dwarf supernovae in distant galaxies, not massive star supernovae.

B) White dwarf supernovae are much more common than massive star supernovae.

C) White dwarf supernovae follow a period-luminosity relation, while massive supernovae do not.

D) White dwarf supernovae all have roughly the same true peak luminosity, while massive supernovae come in a wide range of peak luminosities.

Answer: D

12) Suppose an elliptical galaxy is so far away that we cannot see even its brightest stars individually. Which of the following techniques might allow us to measure its distance?

A) We could use main-sequence fitting.

B) We could use Cepheid variables as standard candles.

C) We could use a white dwarf supernova as a standard candle.

D) We could use radar ranging.

Answer: C

13) What is the best way to determine a galaxy's *redshift*?

A) Find the galaxy's apparent distance, and look up the redshift based on Hubble's law.

B) Find the color of the galaxy, and estimate its distance based on how red the galaxy is.

C) Take a spectrum of the galaxy, and measure the difference in wavelength of spectral lines from the wavelengths of those same lines as measured in the laboratory.

D) Measure the magnitude of the galaxy, estimate its distance, and calculate its redshift using Hubble's law.

Answer: C

14) Which statement below correctly describes the relationship between expansion rate and age for the universe?

A) The faster the rate of expansion, the younger the age of the universe.

B) The faster the rate of expansion, the older the age of the universe.

C) Age is independent of the expansion rate.

Answer: A

15) What does *cosmological redshift* do to light?

A) makes it brighter

B) stretches its wavelength

C) makes it slow down

D) makes all light infrared

Answer: B

16) The lookback time of the cosmological horizon is

A) the Big Bang.

B) the age of the universe.

C) 1 billion years.

D) 10 billion years.

Answer: B

17) Why can't we see past the *cosmological horizon*?

A) Beyond the cosmological horizon, we would be looking back to a time before the universe was born.

B) We do not have big enough telescopes.

C) The cosmological horizon is infinitely far away, and we can't see to infinity.

D) Every galaxy in the entire universe (not just the observable universe) exists within the cosmological horizon, so there's nothing to see beyond it.

Answer: A

18) Hubble's constant is about 22 km/s/million light-years, implying an age of about 14 billion years for the universe. If Hubble's constant were 11 km/s/million light-years, the age of the universe would be about

A) 7 billion years.

B) 14 billion years.

C) 28 billion years.

D) Impossible to say, because Hubble's constant has no relationship to the age of the universe.

Answer: C

19) Given that the universe is about 14 billion years old, which of the following statements is logically valid?

A) All galaxies nearby us are about 14 billion years old.

B) All galaxies that we can see are about 14 billion years old.

C) All galaxies that we see have an age that is approximately equal to the age of the universe today, minus the lookback time (or light travel time) corresponding to the redshift of that galaxy.

D) The oldest galaxies we see at great distances are younger than the oldest galaxies we see nearby.

Answer: D