Select the answer that is the most appropriate among the choices given.

1. What is the Hubble law?
(A) a relation between a galaxy’s mass and radius.
(B) a rule that describes the spacing between the solar system planets.
(C) a relation between a galaxy’s shape and gas content.
(D) a relation between a galaxy’s distance and size.
(E) a relation between a galaxy’s distance and recession speed.

2. Astronomers can determine the mass of a galaxy by
(A) measuring its magnetic field strength.
(B) the size of the radar echoes.
(C) using a REALLY big scale.
(D) measuring the size and orbital speed of gas and stars.
(E) measuring its color and redshift.

3. What is the mass of the Milky Way Galaxy?
(A) $10^5 M_\odot$  (B) $10^8 M_\odot$  (C) $10^{11} M_\odot$  (D) $10^{14} M_\odot$  (E) $10^{15} M_\odot$

4. What are the oldest objects in the Milky Way that astronomers use to date its age?
(A) comets (B) molecular clouds (C) open clusters (D) globular clusters (E) supernova remnants

5. Where are most young stars found in the Milky Way Galaxy?
(A) in the halo (B) in globular clusters (C) in spiral arms (D) near the Sun (E) the outer edge of the MW disk

6. What holds a galaxy cluster together?
(A) galaxy chains (B) pressure from cosmic microwave background radiation (C) grand unified force (D) weakly interacting cosmic gluon (E) gravity of dark matter

7. The cosmic background radiation is
(A) light from very distant stars.
(B) an explanation for the Olbers’ Paradox.
(C) energy emitted by black holes at the centers of galaxies.
(D) radiation from the birth of the Universe.
(E) light from gravitational lenses.

8. The idea that the universe is homogeneous and isotropic and no special location exists is
(A) Kepler’s law. (B) Newton’s principles. (C) intelligent design. (D) cosmological principle. (E) Gilligan’s Island.
9. Which of the following statement about dark matter is incorrect?
   (A) Most of the matter in the Universe is dark.
   (B) MACHOs and WIMPs are possible components of dark matter.
   (C) We know little about dark matter other than they exist.
   (D) Gravity working on this matter is responsible for the hierarchical large scale structures.
   (E) The mass-to-light ratio for dark matter is very small.

10. Hubble classified galaxies for his “tuning fork” diagram using
    (A) mass and diameter of galaxies.
    (B) color and disk characteristics of galaxies.
    (C) texture and clumpiness of galaxies.
    (D) distance and recession velocity of galaxies.
    (E) All galaxies are created equal, Hubble said.

11. What is the evidence that galaxies contain lots of dark matter?
    (A) Rotation speed of stars and gas remain flat even at the edge of the visible disk.
    (B) Measuring mass of any galaxy is really difficult.
    (C) Dark bands are often seen in galaxies.
    (D) Pop I and Pop II stars are both found in most galaxies.
    (E) Some galaxies are not as bright as others.

12. Dr. Albert believes that the Hubble constant is 55 km/s/Mpc. Dr. Edwin believes that is 80 km/s/Mpc. Knowing this information, which statement below is correct?
    (A) Dr. Albert believes that the universe is expanding, but Dr. Edwin does not.
    (B) Dr. Albert believes that the universe is older than what Dr. Edwin believes.
    (C) Dr. Albert believes that the universe will someday stop expanding, while Dr. Edwin does not.
    (D) Dr. Albert believes that the universe is open while Dr. Edwin does not.
    (E) Dr. Albert believes that space travel is possible while Dr. Edwin does not.

13. One reason we believe why active galaxies have a tiny region of activities is that
    (A) they are drawing in matter to their core.
    (B) we see no radiation from their cores.
    (C) they change in brightness on short time scales.
    (D) they tend to have big halos.
    (E) all galaxies have the same brightness.

14. Why can’t we see past the cosmological horizon?
    (A) The universe extends only to this horizon.
    (B) The cosmological horizon is infinitely far away, and we cannot see to infinity.
    (C) We do not have telescope big enough.
    (D) We do not have sensitive enough detectors.
    (E) The light originating from points beyond the cosmological horizon has not reached us yet.

15. The diameter of Galaxy A is the same as Galaxy B, but it rotates twice as fast. How much heavier is Galaxy A compared to Galaxy B?
    (A) \(\sqrt{2}\) times (B) 2 times (C) 4 times (D) 8 times (E) Their masses are the same.
16. How large was the size of the universe at a redshift (z) of 1.0 compared that of the present day universe?
(A) 1/4  (B) 1/2  (C) 1.0  (D) 2.0  (E) Not enough information is given.

17. Gravitational lensing occurs when
(A) massive objects bend light beams that are passing nearby.
(B) massive objects cause more distant objects appear much smaller than they should.
(C) dark matter builds up in a particular region of space, leading to a very dense region with a high mass-to-light ratio.
(D) telescope lenses are distorted by gravity.
(E) massive objects cause more distant objects appear much redder than they should.

18. What is a quasar?
(A) a starlike object that actually represents a bright patch of gas in the Milky Way
(B) a very large galaxy thought to be formed by the merger of several smaller galaxies, typically found in the center of a galaxy cluster
(C) a specialized astronomical instrument for observing distant stars
(D) another name for very bright stars of spectral type O
(E) the extremely bright center of a distant galaxy, thought to be powered by a massive black hole

19. Which of the following best describes dark matter?
(A) Mass that disappears into black holes.
(B) Mass made of anti-matter whose effect cancels out the gravity of ordinary matter.
(C) Mass that radiates at radio wavelengths and is thus invisible in ordinary light.
(D) Mass deduced to be present from its gravitational effect but which emits no visible light or other detectable radiation.
(E) Part of your brain that is susceptible to evil thoughts.

20. A galaxy with a mass-to-light ratio of 100 solar mass per solar luminosity indicates that
(A) the galaxy is very massive.
(B) the galaxy is not very massive.
(C) on average, each solar mass of matter in the galaxy emits less light than our Sun.
(D) on average, each solar mass of matter in the galaxy emits more light than our Sun.
(E) most stars in the galaxy are more massive than our Sun.

21. The age of the Universe can be deduced from
(A) Hubble law  (B) Kepler’s third law  (C) Murphy’s Law
(D) inverse square law  (E) Shapley’s law

22. Our view of the night sky could have been drastically different if the location of the Sun within the Milky Way were different. What would be the location of the Sun if your night sky looked like a field of lights below, like the view from an airplane landing over a sprawling city at night?
(A) in the Milky Way bulge
(B) in the Milky Way disk
(C) in the Milky Way halo
(D) inside a giant molecular cloud
(E) inside a planetary nebula
23. An astronomer now living in another galaxy far from us would see
(A) about 1/2 of all galaxies coming toward him and 1/2 going away from her.
(B) almost all galaxies going away from her.
(C) many more nearby quasars than we do.
(D) our Galaxy approaching hers.
(E) a much younger universe.

24. The most radical transformation of galaxies are caused by
(A) dust obscuration.  (B) supernova explosions.  (C) the oldest stars.
(D) collisions with other galaxies.  (E) college education.

25. How did astronomers such as H. Shapley first determine that the Sun was not in the center of the Milky Way Galaxy?
(A) by looking at the shape of the “milky band” across the sky.
(B) by measuring the direction of the interstellar wind.
(C) by mapping the distribution of globular clusters in the galaxy.
(D) by seeing the retrograde motions of other stars.
(E) by looking at other nearby spiral galaxies.

26. The most immediate future for the Local Group of galaxies is
(A) a collision between the MW and M31 galaxy.
(B) disintegration by the Hubble expansion.
(C) turning into a giant black hole.
(D) formation of a giant pancake.
(E) inflation into a super cluster.

27. Giant density waves triggered by a tidal disruption or by a stellar bar are
(A) ripples in the cosmic microwave background.
(B) giant jets and plumes seen around radio galaxies.
(C) dark matter halo surrounding elliptical galaxies.
(D) spiral arms in disk galaxies.
(E) monster waves on Gilligan’s Island.

28. Olbers’ paradox addresses the question:
(A) Why is the sky dark at night?
(B) Why is the universe “open”?
(C) Why is the universe “closed”?
(D) Why do some galaxies move toward each other?
(E) To be or not to be?

29. Which of the following is the likely resolution of Olbers’ paradox?
(A) Dust blocks our view of distant stars.
(B) Black holes absorb the light.
(C) The Universe has a finite age or size.
(D) Light disappears as it crosses space.
(E) It was much ado about nothing.
30. One of the principle predictions of the Big Bang theory is
(A) quasars. (B) rapidly rotating galaxies. (C) cosmic background radiation.
(D) dark matter. (E) white dwarf supernovae.

31. The “Great Wall” and the “Stick Man” refer to
(A) punishments for failing this exam.
(B) nicknames for two famous radio galaxies.
(C) two summer constellations.
(D) large scale structures found in galaxy surveys.
(E) aspects of a theoretical model for a black hole powered jet.

32. If all the dark matter in the universe were to be instantaneously removed somehow, which of
the following would not happen?
(A) The Moon would fly away from the Earth.
(B) The Milky Way would fly apart.
(C) Clusters of Galaxies would fly apart.
(D) The Universe would expand forever.
(E) The mass-to-light ratio of galaxies would decrease.

33. How soon after the Big Bang did most of the hydrogen and helium in the universe form?
(A) $10^{-42}$ second.
(B) $10^{-3}$ second.
(C) 1 second.
(D) 100 second.
(E) 1 million years.

34. Starburst galaxies are
(A) the most famous 100 galaxies in the sky known to us.
(B) currently forming stars at an unsustainable rate.
(C) also known as quasars and Seyfert galaxies.
(D) answers to the missing mass problem.
(E) sources of the cosmic microwave background.

35. The Universe seems to be open. To make it closed requires
(A) more mass. (B) less mass. (C) a higher rate of expansion.
(D) both (B) and (C). (E) older stars.

36. Why are telescopes sometimes called “time machines”?
(A) because the author, H. G. Wells, used the term to describe telescopes in a book.
(B) because some of the oldest telescopes are still in use today.
(C) because observations of distant objects reveal them as they were in the past.
(D) because pictures of any galaxy at different ages can be taken by changing the magnification.
(E) Its a journalistic misnomer: you cannot travel into the past or the future.
37. If the Hubble constant were 10 times larger,
(A) the age of the universe would be 10 times larger.
(B) your cosmic horizon would be 10 times smaller.
(C) the recession speed of M51 would be 10 times smaller.
(D) you would weigh 10 times more.
(E) the universe would be closed.

38. As late as 1965, continuous creation of matter and space was thought to be as good an explanation for the Hubble expansion as the Big Bang theory. Which of the following observational facts finally established that there was indeed a hot beginning to the universe?
(A) dark matter  (B) globular cluster  (C) cosmological principle  (D) supernova
(E) the cosmic microwave background.

39. The smoothness problem of the standard Big Bang theory
(A) states that the cosmic background is 2.7 K.
(B) comes from the fact that there was just one Bang.
(C) refers to the fact that the cosmic background is nearly identical in all directions.
(D) is an imaginary problem because we cannot measure how smooth the universe directly.
(E) is solved by the equation $E = mc^2$.

40. What does “the Big Crunch” refer to in cosmology?
(A) the final exam week for an astronomer teaching Astro 114.
(B) the collision between the Milky Way galaxy and M31.
(C) the explosion at the center of the Milky Way that created a massive black hole.
(D) the final collapse of the universe onto itself if the universe has enough matter in it.
(E) original name for the Big Bang before the legal settlement with the Nestlé Corporation.
Part 2

NAME:

SPIRE ID:

Write your name and ID number first. Answer all of the following questions to your best ability. Show as much of the intermediate steps as possible so that you can receive partial credit.

41. Galaxy A is located at a distance of 10 Mpc (about 30 million light years).

(a) If the Hubble constant is 100 Mpc/km/s, what is apparent recession speed of Galaxy A?

(b) A new supernova explosion was seen in this galaxy yesterday. When did this supernova explosion actually happen?

(c) Crabbium has an emission line at a wavelength of 300 micron. What would be the observed wavelength of this Crabbium line originating from Galaxy A when you measure it using a telescope?
42. The Big Bang theory is the fundamental basis for the modern cosmology.

(a) List the three main observational evidence for the Big Bang.

(b) List the four shortcomings of the standard Big Bang theory.

(c) What are the possible solutions or explanations for each of these shortcomings?

43. BONUS QUESTION. List the titles of three songs or instrumental music I played at the beginning of each lecture this semester.