

Name: (Answer Key)

**Directions:** Listed below are twenty (20) multiple-choice questions based on the material covered by the lectures thus far. Choose the correct response from those listed, **along with at least a one (1) sentence justification for your answer**. Alternate justification techniques include math calculations and labeled sketches. Each question is worth 5 points: 2 for the letter response and 3 for the justification. Collaboration with your peers is permitted, but all justifications must be in your own words. If you are unsure about a question, make an educated guess, and justify your guess (which can include why you can rule out certain choices from the list). If you get stuck, **please seek assistance from your peers, the TA, or the professor**. Note: It may be helpful to place your answers on a separate sheet of paper and staple it to this assignment sheet.

**WARNING:** Please **DO NOT** copy material word for word from sources such as textbooks, a peer's notes, online references (i.e. Google or Wikipedia), etc in any responses to homework, quiz, or exam questions. Ideas should be expressed in your own words. Not only does this protect you from illegal acts of plagiarism and/or accusations of cheating, but it also aids your future studying by having ideas expressed in a way that you, personally, can best understand. If for some reason you **MUST** quote text from a source in your answer, properly reference your quote.

1. Which of the following types of stars is not found in the halo of our galaxy?
  - A) O-type stars
  - B) Population II stars
  - C) K-type stars
  - D) RR Lyrae stars
2. The Milky Way is an example of which type of galaxy?
  - A) irregular
  - B) elliptical
  - C) lenticular (S0)
  - D) spiral
3. How is cool neutral hydrogen gas, H I, detected in the spiral arms of galaxies?
  - A) by its Balmer line emissions from hydrogen gas
  - B) by its absorption of infrared radiation from distant galaxies
  - C) by its ultraviolet Lyman  $\alpha$  hydrogen-line emissions
  - D) by its 21-cm radio emissions
4. What quantum transition occurs inside a cool hydrogen atom to produce a 21-cm radio photon?
  - A) The electron combines with the proton in the nucleus to become a neutron, producing energy.
  - B) An electron reverses the direction of its motion in orbit around the proton.
  - C) An electron in the ground atomic state reverses its direction of spin with respect to that of the proton.
  - D) An electron falls from the level  $n = 100$  to the level  $n = 99$  in the atom.

5. When we measure the narrow line emissions of hydrogen at 21-cm radio wavelength along a particular line of sight through the disk of our galaxy, we can tell the distances to different hydrogen clouds because
  - A) clouds at different distances have different Doppler shifts because of the rotation of the galaxy.
  - B) the further away the gas cloud, the greater the delay in the arrival time of the 21-cm emission.
  - C) clouds that are further away have smaller angular sizes.
  - D) the emission is weaker from clouds that are further away.
  
6. Which kind of stars are the major source of energy for the heating of the dust clouds and the H II emission nebulae within the planes of the Milky Way and other galaxies?
  - A) hot, young O and B stars, via their UV radiation
  - B) the numerous old, red giant K and M stars, via their IR heat radiation
  - C) very hot white dwarf stars, the remnants of planetary nebulae in the gas clouds
  - D) the very many nova and supernova explosions of stars within the gas and dust clouds
  
7. What is the distribution of molecular clouds in our galaxy and other similar galaxies?
  - A) They occur primarily in the spiral arms.
  - B) They are distributed uniformly throughout the disk.
  - C) They are concentrated close to the galactic center.
  - D) They are distributed throughout the halo, with greater density toward the center.
  
8. The Sun's location in our galaxy is
  - A) in the disk of the galaxy, inside a spiral arm or segment of a spiral arm.
  - B) in the disk of the galaxy, between and well away from any spiral arm.
  - C) We cannot tell where we are located because our view is too severely blocked by interstellar dust.
  - D) in the halo, somewhat above and outside of the spiral arms.
  
9. We aim our radio telescope at a distant region of our galaxy and detect 21-cm radio waves with no Doppler shift. Each of the following is a possible explanation *except one*. Which is the exception?
  - A) The neutral hydrogen in this region is not moving relative to the Earth.
  - B) The neutral hydrogen in this region is moving perpendicularly across our line of sight.
  - C) The neutral hydrogen in this region is in a circular orbit around the galactic center at the same radius as the solar system.
  - D) The neutral hydrogen in this region is moving away from us instead of toward us.
  
10. How is the mass of the galaxy estimated?
  - A) by observing the bending of light from distant galaxies as it passes near the Milky Way center.
  - B) by observing its movement toward neighboring galaxies because of gravitational attraction
  - C) by counting stars and assuming an average stellar mass
  - D) by applying Newton's extension of Kepler's laws to the motion of the Sun and other stars
  
11. Much of the mass of our galaxy appears to be in the form of "dark matter" of unknown composition. At present this matter can be detected only because
  - A) it bends light from distant galaxies and quasars.
  - B) it emits synchrotron radiation.
  - C) its gravitational pull affects orbital motions of matter in the galaxy.
  - D) it blocks out the light from distant stars in the plane of our galaxy.

12. Because the rotation curve for the Milky Way galaxy is approximately flat, a star in a circular orbit 13,000 kpc from the galactic center has the same orbital speed as the Sun, namely 220 km/sec. How much mass is interior to this star's orbit? (Hint: Another potentially useful fact is that the Sun's orbital period around the Galaxy is 230 million years.)
- A)  $9.0 \times 10^{10} M_{\odot}$
  - B)  $1.5 \times 10^{11} M_{\odot}$
  - C)  $9.0 \times 10^{11} M_{\odot}$
  - D)  $1.5 \times 10^{12} M_{\odot}$
13. Which of the following has *not* been proposed as a candidate for dark matter?
- A) massive compact halo objects
  - B) weakly interacting massive particles
  - C) dark nebulae
  - D) Neutrinos
14. The density wave that produces the spiral arm in the Milky Way Galaxy is similar in properties to a
- A) light wave.
  - B) wave on a stretched string.
  - C) Compression wave.
  - D) Gravitational wave.
15. The center of our Milky Way Galaxy can be observed most easily at which of the following wavelengths?
- A) ultraviolet light.
  - B) hydrogen Balmer  $H_{\alpha}$  light.
  - C) infrared and radio radiation.
  - D) highly penetrating gamma rays.
16. The possible presence of a supermassive black hole at the center of our galaxy has been deduced from
- A) powerful magnetic fields in the huge filaments arching away from (or toward) the center.
  - B) the number of globular clusters that are concentrated near to the galactic center.
  - C) Gravitational radiation being emitted from stars as they are swallowed by the black hole.
  - D) the very high orbital speed of stars close to the galactic center.
17. The most important electromagnetic bands for studying the galactic center do *not* include which one of the following?
- A) Infrared
  - B) Visible
  - C) Radio
  - D) X ray
18. The star S2 orbits Sagittarius A\* with a period of 15.2 years and a semimajor axis of 950 AU. What does Kepler's Third Law suggest as the total amount of mass inside the orbital radius of S2?
- A)  $1.3 \times 10^6 M_{\odot}$
  - B)  $2.6 \times 10^6 M_{\odot}$
  - C)  $3.7 \times 10^6 M_{\odot}$
  - D)  $9.4 \times 10^9 M_{\odot}$

19. A Cepheid variable star with a pulsation period of a few days is seen in the spiral arm of a galaxy. Its apparent brightness is measured as  $10^4$  times fainter than an equivalent Cepheid star with the same period 1000 ly away from the Sun in our galaxy. Assuming no light absorption between galaxies, what is the distance to the far Cepheid, and hence to the galaxy?
- A) 100,000 ly (100 times further away)
  - B) 10 ly (100 times closer)
  - C)  $10^7$  ly ( $10^4$  times further away)
  - D) 10,000 ly (10 times further away)
20. Why do the spiral arms show up so clearly in spiral galaxies?
- A) Stars are spread uniformly over the galaxy but the dust forms a spiral pattern, absorbing starlight; the spiral arms are the dust-free regions between the dust lanes.
  - B) Stars are spread almost uniformly throughout the disk of the galaxy outside the nuclear bulge, but the brightest stars occur only in the spiral arms, making the arms stand out.
  - C) There are many more stars in the arms than in the regions between the arms, so the arms stand out distinctly.
  - D) Stars occur only in the spiral arms (and the nuclear bulge), with essentially none between the arms, making the arms stand out brightly.

## Answer Key

1. A
2. D
3. D
4. C
5. A
6. A
7. A
8. A
9. D
10. D
11. C
12. B
13. C
14. C
15. C
16. D
17. B
18. C
19. A
20. B