Ay 1

2009 FINAL EXAM

June 3, 2009

Name: _____

Ay 1 Section: _____

The questions should be answered in 3 hr using **open personal and class notes** (but do not consult the textbook, other books, or use the web except to view the class notes). If you take more than 3 hours, you must indicate which questions you have answered after time. You should answer all multiple choice questions in Section A, using the attached answer grid. Answer **3 of the 5 essay questions in Section B**, and **2 of the 3 computational questions in Section C**. Write your answers to parts B and C on separate sheets of paper or a bluebook.

Each of the 48 multiple choice questions are worth 1 point each, while each of the essay and computation questions in Sections B and C are worth 10 points each. Calculators may be used for computation only. All necessary constants are included on the next page. (If there is something left out that you need, please write an explanatory note to the grader and this will be taken into account.) In several multiple choice questions that are multiple nearly correct answers – READ ALL CHOICES BEFORE SELECTING THE BEST.

When you have finished the exam, write your name and Ay 1 section on the multiple choice grid answer sheet and staple your essays to it. Hand it in to Gina Armas in 246 Cahill or your TA. (Be sure to write your name and section number on all parts of the exam!)

Seniors: Due by 3:00 PM, Friday, June 5.
Non-Seniors: Due by 3:00 PM, Friday, June 12.

Constants

You may find the following helpful:

$G = 6.67 \times 10^{-11}\ m^3\ kg^{-1}\ s^{-2}$

$c = 3.00 \times 10^{8}$ m/s

$k = 1.38 \times 10^{-23}$ J/K

mass of sun $= 1.99 \times 10^{30}$ kg

radius of sun $= 6.96 \times 10^{5}$ km

mass of earth $= 5.97 \times 10^{24}$ kg

radius of earth = 6378 km

1 arcsecond $= 4.85 \times 10^{-6}$ radians

1 AU (astronomical unit) $= 1.50 \times 10^{8}$ km

1 eV $= 1.60 \times 10^{-19}$ J

1 parsec $= 3.09 \times 10^{13}$ km

1 year $= 3.16 \times 10^{7}$ s

mass of proton $= 1.67 \times 10^{-27}$ kg

mass of electron $= 9.11 \times 10^{-31}$ kg

fundamental charge $= 1.60 \times 10^{-19}$ C

distance to Galactic center = 8.5 kpc

SECTION A: Multiple Choice

ON THE MULTIPLE CHOICE QUESTIONS, READ ALL CHOICES AND CHOSE THE BEST ONE. IN SEVERAL CASES, THERE ARE MULTIPLE CORRECT ANSWERS, AND YOU NEED TO CHOOSE THE ANSWER THAT LETS YOU COMBINE THEM!

1. What is the approximate diameter of the Milky Way galaxy?
    a) 3 pc
    b) 30 pc
    c) 30 kpc
    d) 30 Mpc
    e) due to the dust, we can't determine it

2. Active galaxies (AGN) are powered by
    a) accretion inflow around supermassive black holes
    b) dark matter collisions in colliding galaxies
    c) dark energy release in large scale structures
    d) starburst clusters in colliding galaxies
    e) none of the above

3. The Magellanic Clouds are
    a) high atmospheric clouds seen in the tropics
    b) nebulae within our own galaxy
    c) small galaxies in orbit around the Milky Way
    d) distant galaxy clusters
    e) spots seen in the cosmic microwave background

4. Absorption lines seen in spectra of stars are formed by
    a) dark filaments in the stellar atmosphere
    b) motion of gas in convection zones
    c) excess hydrogen in the center of the star
    d) photon absorption in quantum transitions by cool gases in the atmosphere
    e) photon emission in quantum transitions by cool gases in the atmosphere

5. The rotation velocities within most spiral galaxies
    a) decrease strongly with radius
    b) increase steeply all the way to the edge of the galaxy
    c) rise in the center of the galaxy and then remain approximately constant all the way to the edge of the galaxy
    d) cannot be measured due to dust
    e) imply that all galaxies in each galaxy cluster formed at the same time

6. Observations of the CMB indicate that we live in a flat universe. Suppose we see a distant galaxy that appears 1 arcsecond wide. If the universe were open, the size of this galaxy would
    a) appear smaller
    b) appear larger
    c) appear the same size
    d) depend on the type of galaxy
    e) depend of the luminosity of the galaxy

7. The major mass component to our Galaxy at large radius
    a) is in stars
    b) in interstellar gas and dust clouds
    c) consists of dark matter
    d) the sum of a and b
    e) in globular clusters

8. Which planet is only seen at night within few hours after sunset or before sunrise?
    a) Venus
    b) Saturn
    c) Earth
    d) Jupiter
    e) Moon

9. The technique of interferometry
    a) uses light combined from multiple telescopes
    b) was first attempted using x-ray telescopes
    c) improves the angular resolution of observations
    d) a and c
    e) all of the above

10. What is the cosmic microwave background (CMB)?
    a) low-wavelength radiation from distant quasars
    b) light from accretion disks around black holes at the centers of galaxies
    c) blackbody radiation from the early universe
    d) remnant light from the reionization of the universe
    e) radiation from the early inflation period

11. The full moon rises at approximately [again – you can make a drawing to check your answer]
    a) sunrise
    b) noon
    c) sunset
    d) midnight

12. A total eclipse of the sun
    a) can only occur at nearly full moon and close to 12 noon
    b) must occur near new moon but will only be visible from part of the earth
    c) can only occur when the earth is perihelion
    d) is very dangerous during totality
    e) is vastly overrated (please don't choose this one!)

13. If you are at the North Pole,
    a) the sun will never rise
    b) the moon will never be seen
    c) the north star (Polaris) will be overhead
    d) the north star will rise and set on the southern horizon
    e) you are likely to be eaten by a polar bear migrating south for the winter

14. If the dwarf planet Ceres was moved from its current orbit of 2.6 AU to Jupiter's orbit (5.2 AU), its temperature would approximately
    a) become 2 times higher
    b) remain unchanged
    c) become 1/2 its current temperature
    d) become $1/2^{1/4}$ of its current temperature
    e) become $1/\sqrt{2}$ of its current temperature

15. On the trip to Palomar Observatory, we observed a planetary nebula through the 60-inch telescope. What is a planetary nebula?
    a) gas and dust in the process of forming a planet
    b) ejected material from a supernova
    c) a dwarf galaxy
    d) an extrasolar planetary system immersed in dust
    e) the photo-ionized, expelled envelope of a giant star

16. Which of the following statements is true about x-ray telescopes?
    a) they operate typically from ground and are coated with photographic emulsion
    b) many use grazing incidence mirrors to reduce absorption of the x-rays
    c) most are refracting telescopes using liquid mercury
    d) they are generally used underground to avoid cosmic rays
    e) none of the above

17. The angular resolution of a 10 m diameter telescope (operating at the diffraction limit) most strongly depends on which of the following?
    a) whether it is a reflecting or refracting telescope
    b) its height within its dome
    c) the latitude of the observatory
    d) the height of the mountain on which it is located
    e) the wavelength of the radiation it is observing

18. A photon from the sun hits you on the nose! About how long ago was the energy of the photon generated near the center of the sun?
    a) a fraction of a second ago
    b) 8 minutes ago
    c) 1 year ago
    d) 1 million years ago
    e) 14 billion years ago

19. Nuclei heavier than iron (like uranium) are thought to have been produced
    a) when the earth was 4.5 billion years old
    b) by fusion during the late red giant phase of stellar evolution
    c) during supernovae explosions
    d) in the Big Bang
    e) on interstellar dust grains

20. The main sequence phase of stellar evolution is
    a) the final phase in which very heavy elements are synthesized
    b) when a star is most likely to undergo a supernova explosion due to the high H abundance
    c) the initial phase in which H is fused to He
    d) the phase when the entire star is undergoing nuclear fusion
    e) the most luminous phase in a star's evolution

21. Stars distributed along the main sequence
    a) differ primarily in their total mass (upper end of main sequence having higher masses)
    b) have differing compositions (more He at the lower end of the main sequence)
    c) have differing rotation rates (increasing strongly to the lower end of the main sequence)
    d) have differing ages (upper end of main sequence having older stars)
    e) have different percentages of dark matter

22. On the main sequence, a more massive star will have ..... than a less massive star.
    a) lower internal temperatures because there is more gravitational attraction
    b) higher internal temperatures because there is more fuel to burn
    c) higher internal temperatures because it needs a higher gas pressure to counterbalance gravitational forces
    d) a longer evolutionary time since it has more fuel
    e) none of the above – stars with different masses do not have the same evolutionary phases

23. The orbits of the planets in our Solar System suggest that
    a) planetary systems formed in the first thousand years of the universe from H and He
    b) only rocky planets can form in the outer solar system
    c) there can only be one gas giant planet in any solar system
    d) all planets were once a single giant planet that later split apart
    e) all the planets formed more or less simultaneously rather than being individually captured later on

24. Which of the following is the most likely scenario for the formation of a galaxy like our Milky Way?
    a) a giant elliptical galaxy broke apart to become multiple spiral galaxies
    b) all spirals formed in a single catastrophic collapse of gas in the early Universe
    c) the protogalaxy formed and acquired angular momentum during the inflationary epoch of the early Universe
    d) they are a result of a multi-stage process of merging and buildup from smaller sub-galaxies
    e) they result from spiral structure of the Cosmic Microwave Background, imprinted on early cosmic gas

25. The formation of stars like the sun
    a) occurs by gravitational collapse of interstellar gas clouds
    b) only occurred in the early universe since galaxies have now used up their starforming gas
    c) can only occur when two galaxies collide
    d) is initiated by dark matter condensation
    e) none of the above

26. Which of the following statements about radial velocity searches for extra-solar planets is true? [Radial velocity is the velocity component towards or away from the observer.]
    a) they have found only earth mass planets
    b) they are easier to do if the orbit of the planet is perpendicular to the line of sight
    c) they take advantage of varying Doppler shifts
    d) they are most sensitive to planets with close-in orbits and large masses
    e) c and d

27. Which wavelengths of radiation are most *difficult* to detect from the center of our Galaxy?
    a) visible
    b) near infrared
    c) far infrared
    d) microwave
    e) radio

28. Which methods allow distances to galaxies to be measured?
    a) Variable stars (such as Cepheids and RR Lyrae)
    b) Supernovae
    c) Parallax
    d) a and b
    e) b and c

29. Astronomers use spectra of individual stars to determine
    a) the elemental abundances in the stellar atmospheres
    b) the stellar motions along the line of sight
    c) the stellar surface temperature
    d) the stellar fusion reactions
    e) a, b and c

30. Gamma Ray Burst (GRB) sources are
    a) believed to be within our galaxy and result from decay of cosmic rays
    b) are at large distances and may be due to collapse of the core of a massive star to form a black hole at its center
    c) are believed to result from collisions of neutron stars with normal star like the sun
    d) associated with quasars and due to stars crossing the event horizon
    e) b and d

31. Pluto orbits the sun at approximately 40 AU. How long is a year on Pluto? [Hint: Use Kepler's third law, or derive it from balancing the centripetal/centrifugal force with the sun's gravitational force on Pluto versus Earth.]
    a) 1 year
    b) 40 years
    c) 250 years
    d) 10,000 years
    e) not enough information

32. The main observable effect of dark energy is
    a) the accelerating expansion of the Universe
    b) the linear relation between galaxy recession velocity and distance (the Hubble law)
    c) flat rotation curves in disk galaxies
    d) Hawking radiation from black holes
    e) the ionization of the intergalactic medium

33. The central temperature of the sun is?
    a) 6000 K, determined by the blackbody color
    b) 600 K, determined by observed spectral lines
    c) 10 million K, determined by physical models
    d) not known
    e) varies rapidly by a factor of two or more

34. How can we directly measure the surface temperature of a star?
    a) by comparing the strengths of spectral lines
    b) by measuring the star's luminosity and radius
    c) by examining the overall shape of the star's spectrum
    d) a, b, and c
    e) we cannot measure it directly, but only predict it through models

35. Pulsars (remember sound recordings in class) are
    a) stars with many neutron-rich isotopes like deuterium
    b) stars fusing neutrons with nuclei heavier than iron
    c) pulsating neutron stars with a stellar wind
    d) rotating neutron stars with strong magnetic fields
    e) extra-terrestrial navigation beacons

36. How do we know the chemical compositions of stars?
    a) from models of stellar structure
    b) from sampling them with probes
    c) from observing their spectra
    d) from theories of star formation
    e) none of the above

37. Stars complete the main sequence phase of stellar evolution when
    a) the He in the envelope of the star sinks to the center
    b) most of the hydrogen in the core has been converted in He
    c) carbon starts undergoing nuclear fusion
    d) most of the core is deuterium
    e) none of the above

38. Cool stars exhibit the spectral lines of molecules like CO and TiO since
    a) the temperature is too low and the hydrogen is all ionized
    b) the molecules use up electrons, leaving fewer for atoms to emit
    c) the surface temperature is low enough for the molecules to survive
    d) these stars have undergone nuclear reactions near the surface
    e) none of the above

39. What is the primary factor that determines whether a star ends up as a white dwarf or a neutron star?
    a) composition
    b) mass
    c) rotation rate
    d) density
    e) luminosity

40. The existence of dark matter is inferred from which of the following observations?
    a) gravitational lensing
    b) rotation curves of galaxies
    c) the observed large-scale structure of the universe
    d) the cosmic microwave background
    e) all of the above

41. If the Hubble constant were measured to be 10 km/s/Mpc, estimate the age of the universe. (Note: the Hubble constant is actually measured to be about 74 km/s/Mpc.)

a) 2 billion years
b) 14 billion years
c) 50 billion years
d) 95 billion years
e) 200 billion years

42. Spiral galaxies can be transformed into ellipticals when

a) they exhaust the gas supply of their disks
b) they star forming stars
c) they engage in a major merger with another galaxy
d) their central black hole becomes a quasar
e) their spiral arms become too tightly wound

43. The main sequence lifetime of a 3 solar-mass star is roughly

a) 1 million years
b) 10 million years
c) 100 million years
d) 1 billion years
e) 10 billion years

44. Gravitational lensing, first predicted by Einstein, involves

a) the mutual effects of two gravitating masses causing orbital precession
b) the curvature of light due to foreground mass along the line of sight
c) a means of manufacturing large optics for telescopes
d) a process that occurred during the early universe, but is no longer relevant today
e) none of the above

45. For two planets at the same distance from the sun, which do you expect to have a higher average surface temperature?

a) the one with smaller mass
b) the one with a layer of thick reflecting clouds
c) the one with a dense atmosphere of molecules but no clouds
d) the one with smaller radius
e) the one with no atmosphere

46. Type Ia supernovae are considered to be good for measuring large distances because

a) nearly every galaxy has such a supernova occurring at any given time
b) they are all of approximately the same luminosity
c) they trace the “dark ages” of the universe
d) their explosions produce remnants of nearly the same size
e) their luminosity is unpredictable but very large

47. The density of material in a neutron star is approximately:

a) similar to that of a white dwarf (10^{7} gr cm^{-3})
b) is similar to that within the atomic nucleus (10^{14} g cm^{-3})
c) the estimates range over 10 orders of magnitude
d) 10^{10} times that within atomic nuclei
e) none of the above

48. In an infinite, static universe, every line of sight eventually runs into a star, and thus the night sky would seem bright in all directions. However, we observe a dark night sky. This conundrum, now resolved by modern cosmology, is known as

a) Kepler’s Paradox
b) Gibbs’s Paradox
c) Laplace’s Paraodx
d) Olber’s Paradox
e) Fermi’s Paradox

Name: ..... Ay 1 Section: .....

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SECTION B: Essay Questions

Write about 2 paragraphs (perhaps aided by a drawing) in answer to **3 of the 5** questions below. These essays do not need to be excessively technical; they can be written as though you were explaining the science to an intelligent person who has not taken an astronomy course. Each question is worth 10 points.

1. Give two methods used to try to detect extrasolar planets, and explain how each works. What are the advantages and disadvantages of each, and what can we learn about the properties of the planets by using them?

2. Describe the evolutionary stages of a solar mass star from formation to death. Include a brief (about 1 sentence) description of each stage. Explain how the stellar evolution differs for a star of much higher mass (e.g., 30 solar masses).

3. What are the reasons to pursue adaptive optics on ground-based telescopes? Explain how this technique works and what the ultimate resolution might be for a 10 m telescope, such as the Keck telescopes in Hawaii, when observing at infrared wavelengths (for instance, 1 micron, i.e. 10^{-6} m).

4. What is inflation? Describe some major problems in cosmology that the theory of inflation solves, and describe how.

5. During the course, we discussed a number of exotic astrophysical objects, such as pulsars, black holes, GRBs, and quasars. Pick one of these and describe its physical properties and how it is observed.

SECTION C: Problems

Select **2 of the 3** questions below to answer. Each is worth 10 points. Please show your work. Credit will be given for the explanation, not only the final answer.

1. The Andromeda Galaxy is a spiral galaxy like our Milky Way at a distance of 780 kpc. Stars rotate about its center at roughly 200 km/s. Suppose you observe Andromeda over a 10 year period. Should you be able to detect the position shifts of stars in Andromeda due to orbital motion, using current optical telescopes equipped with adaptive optics and having a resolution of 0.01 arcseconds?

2. The Square Kilometer Array (SKA) is a large array of radio telescopes currently being planned. It will be able to detect a flux of approximately 10^{-30} W/m^2 in one hour. Earth outputs about 1 MW (megawatt) on each of its ~2000 large broadcast TV stations. What is the greatest distance at which an alien civilization possessing SKA could eavesdrop on our TV leakage? Could a civilization on the other side of the Mliky Way detect us? [Assume that the TV power is emitted isotropically.]

3. The Kepler spacecraft launched on March 6, 2009 and can measure the brightness of stars to a precision of 1 part in 10^5. Will it be able to detect an Earth-like planet eclipsing a star like our Sun?