Name: ______________________

Seat Number: ______________________

Astronomy 102: Stars and Galaxies

Examination 3

April 11, 2003

Do not open the test until instructed to begin.

Instructions: Write your answers in the space provided. If you need additional space, continue on the back of each page, but indicate clearly that you have done so. No books, notes, or assistance from anyone is allowed. You are allowed to use, and will need, a calculator. Please **write legibly and be brief and to the point!** The exam has 13 questions (eight multiple choice and five short answer); you have 50 minutes in which to answer them. All exams must be turned in at the end of the period. The number of points each question is worth is provided for your information; there are a total of 64 points.

Possibly Useful Constants and Formulae

Mass of the Sun: $1\,M_\odot = 2.0 \times 10^{30}\,\mathrm{kg}$

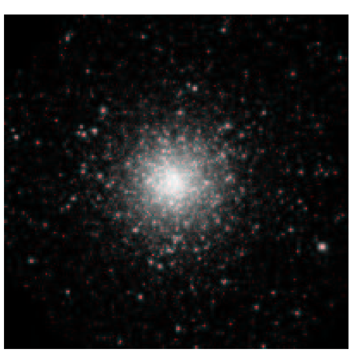
Luminosity of the Sun: $1\,L_\odot = 3.85 \times 10^{26}\,\mathrm{W}$

"High-mass" star: $M > 8\,M_\odot$

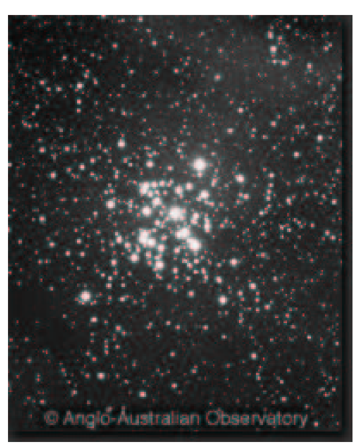
$$R = \frac{2\,G\,M}{c^2}$$

Velocity of Sun's orbit about the Galaxy: $V_0 = 220\,\mathrm{km/s}$

Globular Cluster



Open Cluster



Multiple Choice Questions: The first eight questions are multiple choice. Except where explicitly noted, only one answer is correct for each question. Circle the letter of the correct answer. Each multiple choice question is worth **4 points**

1. The observations mentioned in class of a star orbiting the black hole at the center of our Galaxy were done in infrared light rather than visible light. Why?

(a) The stars in the center of the galaxy are all very old, and thus emit much more of their light at longer wavelenghts.

(b) That close to the supermassive black hole, all of the stars' light is shifted to the red, making it easier to see the stars in the infrared than in visible light.

(c) The dust between us and the center of the galaxy obscures visible light, but infrared light can penetrate it.

(d) The emission from a nebula energized by the black hole in optical wavelengths would overwhelm the light from the stars; to avoid this, astronomers worked in the infrared.

2. Most of the total mass in the Galaxy is in:

(a) The most massive stars.

(b) The much more numerous low-mass stars.

(c) Gas and dust.

(d) The supermassive black hole at the center.

(e) Dark matter.

3. Which of the following is found only in a binary or multiple star system? (**More than one may be correct; circle all that apply.**)

(a) A nova

(b) A Type Ia (thermonuclear) supernova

(c) A Type II (core collapse) supernova

(d) A star whose mass we can measure without resorting to theories of stellar evolution

(e) A star whose luminosity we can measure without resorting to theories of stellar evolution

(f) A pulsar

(g) A white dwarf

(h) A star with planets

4. The moon suddenly and unexpectedly collapses and becomes black hole (while keeping the same mass). Which of the following happens? (Only one is correct.)

(a) The moon would develop an event horizon which is 3 km in radius.

(b) Tides on the Earth would become much more extreme, because tidal forces from the moon-mass black hole would be greater than those from the Moon.

(c) The Earth would be sucked into the black hole where the Moon used to be.

(d) We would thereafter have no way of knowing where the moon was.

(e) None of the above.

5. In a planetary nebula, the shell of expelled material is glowing intensely. What is the source of energy for this glow?

(a) Beams of particles and electromagnetic waves emitted from the magnetic poles of the central spinning star.

(b) The explosion of the dying star.

(c) Ultraviolet radiation from the hot star at the center.

(d) The fusion of hydrogen into helium in the expelled shell.

(e) The change of electrons and protons into neutrons.

6. Some "superstars" give off more than $50,000$ times the luminosity of the Sun. Why are there no such stars among the stars that are close to the Sun?

(a) Because conditions in the neighborhood of the Sun only permit low-mass (low luminosity) stars to form

(b) Because such very luminous stars are extremely rare, and thus any small neighborhood in the Galaxy is unlikely to contain one of them

(c) Because all stars in the vicinity of the Sun have planets, and planets reduce the brightness of a star

(d) Because such superstars are really several hundred stars blending their light together (but so far away that we can't distinguish individual stars); nearby stars are easy to separate.

7. Many of the first batch of planets found outside our solar system were in systems very different from ours, with gas giants the mass of Jupiter in orbits smaller than the Earth's orbit about the Sun. Why is this?

(a) Large planets close to their stars are easier to find both because the gravitational pull of a closer planet on the star is greater, and because the shorter period means you don't have to observe the star as long.

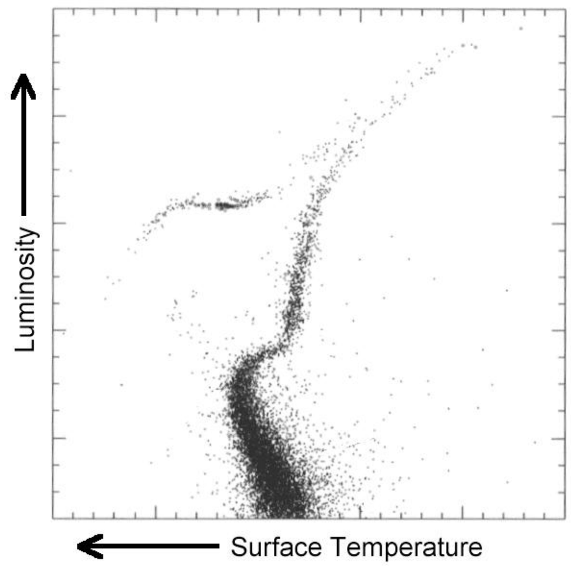
(b) Large planets close to their stars are easier to find because they block out more of the star's light when they pass in front of the star.

(c) Planets close to the star are easier to find because the planet is moving a lot faster than one father out would.

(d) Our Solar System, with gas giants far from the Sun and small rocky planets close to the Sun, is extremely unusual, and it's unlikely there are many others like it.

(e) Many stars are very old, and old stars in the red giant phase lose mass. As stars lose mass, planets spiral in towards the star. We are seeing systems much like our Solar System will be once the Sun is a red giant and Jupiter has moved in a lot closer to the center of the system.

8. Consider the following H-R diagram:



This is the H-R diagram of: (**more than one answer may be correct; circle as many as apply**)

(a) A young group of stars.

(b) An old group of stars.

(c) A group of stars that formed in a short period of time.

(d) A group of stars which have been forming throughout the lifetime of the Galaxy.

(e) A group of stars rich in heavy elements.

(f) A group of stars more massive than the Sun.

(g) A group of stars characteristic of the stars near the Sun in the Galaxy.

(h) A group of stars characteristic of the brightest stars we can see from the Earth.

Short Answer Questions: Answer questions in the space provided. Indicate clearly if you must continue on the back of the page. Include any calculations or diagrams necessary. Some questions require only a word or a few words, others will require a sentence or two of explanation, and others will require a calculation. **Be brief and to the point.**

9. [3 points] An astronomer discovers an extrasolar planet. The planet has the mass of Jupiter, and orbits its primary (a G-type star much like the Sun) in a circle of radius 1 AU. Is it possible that there is life similar to life on Earth in this star system? If not, why not? If so, how so? (Hint: think about what you know of Jupiter or Saturn from observing it in the lab, or even just reading the lab manual.)

10. [8 points] Consider two stars in the sky with which you are probably familiar: Betelgeuse and Sirius. For each of these star systems (described in more detail below), indicate what future astrophysical phenomena we might possibly observe from them (were we to live the requisite huge number of years). In each case, there may be more than one possibility based on the information provided.

(a) Betelgeuse is a red supergiant star of spectral type M which is 130pc distant. It is very large, with a radius of $\sim$ 600 times that of the Sun. Betelgeuse almost certainly started its main sequence life with a mass greater than $12\,M_\odot$; however, it has undergone a lot of mass loss, and is still shedding mass. As such, we are not sure if it will stay over $8\,M_\odot$ throughout its tenure as a supergiant. What are possible astrophysical phenomena that future astronomers might observe from Betelgeuse?

(b) Sirius, the brightest star in the sky, is in fact a binary star system less than 3pc away from the Sun, although only one star is bright enough to see with the naked eye. The brighter star (Sirius A) is a main sequence star of spectral type A; it is about twice as massive as the Sun. The dimmer star (Sirius B) is a carbon white dwarf star in an eccentric orbit about Sirius A with a semi-major axis of about 20 AU. Sirius B has a mass similar to that of the Sun, but is smaller than the Earth. What are possible astrophysical phenomena that future astronomers might observe from Sirius?

11. [8 points] An astronomer observes a very hot, massive young star in the Milky Way galaxy.

(a) In what part of the Galaxy is this star likely to be?

(b) Is this star more likely to be in an open cluster or a globular cluster?

(c) Is there likely to be any interstellar gas near this star? If so, what would you expect to be the state of the interstellar medium near this star?

(d) Qualitatively, how would you expect the abundance of heavy elements in this star to compare to the heavy element abundance in the Sun?

12. [5 points] Describe in three or four sentences what is the primary evidence for the presence of dark matter in our Galaxy; be sure to indicate qualitatively why the observational evidences leads to the conclusion of dark matter.

13. [8 points] An astronomer makes a startling discovery: a main sequence star in the Milky Way whose spectrum shows that the star is composed *only* of Hydrogen and Helium; the spectrum shows no evidence of Oxygen, Iron, or other heavy elements.

(a) The astronomer is very excited about this discovery; why is it so astronomically significant?

(b) Is this star likely to have a planetary system? Why or why not?

(c) Can this star be more massive than the Sun? Why or why not?