Final Exam
79205 Astronomy
Fall 1997

NAME: _____Solution key_____

You have three hours to complete this exam. Part I has 27 multiple choice questions, each worth 2 points, and one one six-point question. Part II has four short problems, each worth 10 points. You are to answer all questions on both parts.

You may use your textbooks (Zeilik & Gregory or Zeilik), other books, and class notes and handouts. You *may not* share these resources with another student during the test.

GOOD LUCK!

		Score
Part I:		_________
Part II:	1.	________
	2.	________
	3.	________
	4.	________

Total Score: ____________

Part I: *Multiple choice worth two points each.*

Give the *best* choice for each question.

___**D**__**1.** Star #1 radiates 16 times as much energy as star #2, but is of the same Harvard spectral class. Which of the following is true, where *T* is "temperature", *R* is radius, and *M* is absolute magnitude?

A. $T_1=2T_2$
B. $R_1=2R_2$
C. $M_1=M_2+3$
D. $M_2=M_1+3$
E. None of the above

___**C**__**2.** Which two solar system bodies would you expect to have atmospheres with similar chemical composition?

A. Earth and Jupiter
B. Earth and Mars
C. Mars and Titan
D. Titan and Ganymede
E. Ganymede and Triton

___**E**__**3.** Which of the following has the lowest average mass density?

A. Mercury
B. Earth
C. The Sun
D. Our Galaxy
E. The Universe

___ **D**___**4.** A flat, circulating disk, with a "jet" emerging from the axis, has been observed in

A. The Crab pulsar
B. Very young stellar objects
C. Active galaxies
D. All of the above
E. None of the above

___**E**___**5.** A satellite orbits the Earth once every 64 minutes. A different satellite orbits the Earth at a distance 16 times as far from the center of the Earth. This satellite completes one orbit in

A. 64 minutes
B. 4.3 hours
C. 17 hours
D. 34 hours
E. 2.8 days

___C__**6.** As a one solar mass star moves off the main sequence and begins to ascend to a red giant, its luminosity comes mainly from

A. Hydrogen core burning
B. Helium core burning
C. Hydrogen shell burning
D. Helium shell burning
E. Gravitational contraction

___E___**7.** Two otherwise identical elliptical galaxies have different redshifts. Galaxy #1 has twice the redshift of Galaxy #2. The apparent magnitude of Galaxy #1 minus the apparent magnitude for Galaxy #2 is

A. -1.5
B. -0.75
C. 0
D. +0.75
E. +1.5

___B___**8.** Which is oldest?

A. M1
B. M3
C. M45
D. M67
E. The Solar System

___C___**9.** A star moves horizontally and to the right on an HR diagram. Which is true?

A. Surface temperature decreases and radius decreases
B. Surface temperature increases and radius decreases
C. Surface temperature decreases and radius increases
D. Surface temperature increases and radius increases
E. Surface temperature decreases and radius stays constant

___B___**10.** Which of the following was first to form in the Big Bang?

A. Hydrogen atoms
B. Helium nuclei
C. Carbon monoxide molecules
D. Stars
E. Galaxies

___E___**11.** A population I Cepheid variable has a 10 day period and apparent visual magnitude of +0.84. The distance to the star is

A. 1 pc
B. 5 pc
C. 10 pc
D. 50 pc
E. 100 pc

___**A**___**12.** A particle of mass m falls from a large distance onto a black hole of mass M. The amount of gravitational energy released is

A. $mc^2/2$
B. mc^2
C. $Mc^2/2$
D. Mc^2
E. Cannot be determined from the information given

___**A**___**13.** Which of the following optical filters would make the central star stand out most clearly in a planetary nebula?

A. Blue
B. Green
C. Yellow
D. Orange
E. Red

___**A**___**14.** Which of the following optical filters would make a nearby dark nebula stand out most clearly in a photograph of it and the background stars?

A. Blue
B. Green
C. Yellow
D. Orange
E. Red

___**B**___**15.** The rotational velocity of stars in our Galaxy is relatively constant at a radius of 10kpc or larger. The same effect is seen in other galaxies. This is evidence for

A. Supermassive black holes
B. The dark matter halo
C. Isolated neutron stars
D. Cold hydrogen gas
E. Spiral arm tracers

___**B**___**16.** Compared with population I stars, population II stars of the same mass

A. Are cooler
B. Are more blue
C. Are less luminous
D. Live twice as long
E. Have twice as much hydrogen

___**B**___**17.** A billion years from now, the Hubble "Constant", compared to today, will be

A. Larger
B. Smaller
C. The same
D. It depends on whether the universe is open, closed, or flat
E. It depends on the amount of "dark matter"

___**E**___**18.** Which of the following increases most rapidly as the spectral class of a main sequence star goes from M to O:

A. Radius
B. Surface temperature
C. Central temperature
D. Magnitude
E. Luminosity

___**C**___**19.** Most of the energy in a supernova explosion is released in the form of

A. Light
B. X-rays
C. Neutrinos
D. Radio waves
E. Kinetic energy of the ejecta

___**B**___**20.** A molecular cloud, collapsing into a protostar, has a surface temperature of 1500K. This phenomenon is best observed in the

A. Radio
B. Infrared
C. Visible
D. Ultraviolet
E. X-ray

___**E**___**21.** You want to resolve a region of cold hydrogen gas in a galaxy using a 100 m diamter radio telescope. If the region is 5kpc in diameter, the galaxy can be no farther away than

A. 5 kpc
B. 25 kpc
C. 100 kpc
D. 500 kpc
E. 2.5 Mpc

The remaining questions in Part I all refer to the sheet of color optical images.

22. Indicate the image (A through F) which best typifies the following classes of objects. *One point for each answer.* Put down only one answer on each line, even if you think there may be more than one possibility.

Elliptical galaxy ______**D**_______

Globular cluster ______**A**_______

Interstellar dust cloud ______**B**_______

Planetary nebula ______**C**_______

Supernova remnant ______**E**_______

Young star cluster ______**F**_______

<u>Note: Be sure to write the correct choice (not "image") in the blank!</u>

___**D**___**23.** The object which is farthest from the Earth is shown in

A. Image A
B. Image B
C. Image C
D. Image D
E. Image E

___**D**___**24.** Which image shows what is left over from what used to be a very massive, main sequence star?

A. Image B
B. Image C
C. Image D
D. Image E
E. Image F

___**B**___**25.** Which image shows what is left over from what used to be an approximately one solar mass, main sequence star?

A. Image B
B. Image C
C. Image D
D. Image E
E. Image F

___**D**___**26.** A regularly pulsating source of light, radio waves, and X-rays, is at the center of

A. Image A
B. Image C
C. Image D
D. Image E
E. Image F

___**E**___**27.** Which image shows stars, most of which are still on the main sequence, but a few of which have evolved off of it?

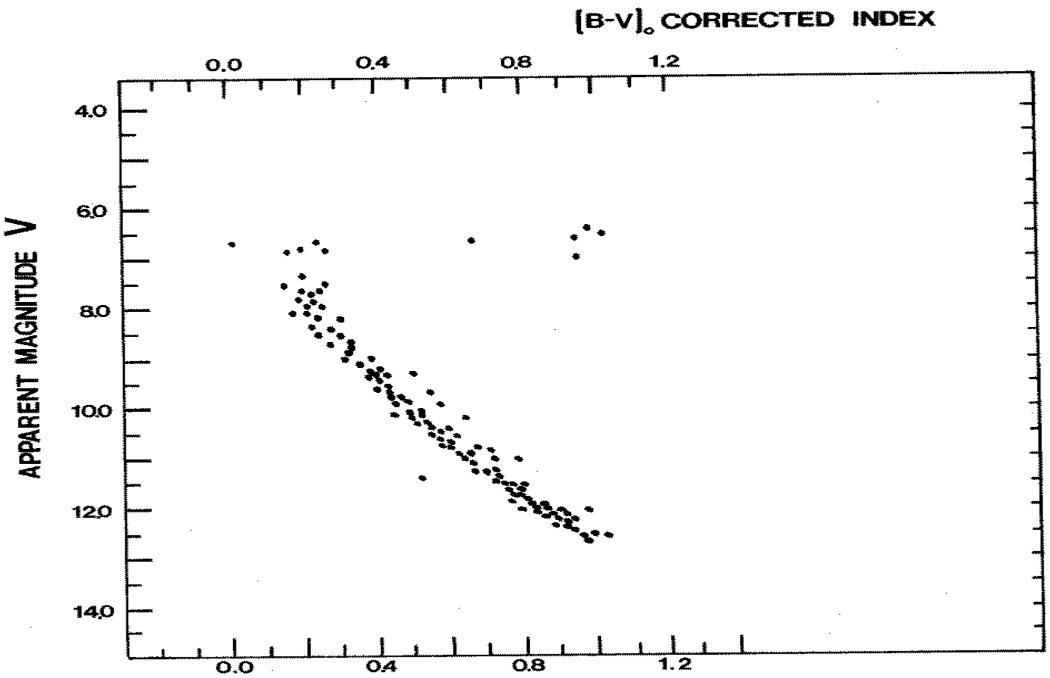
A. Image A
B. Image C
C. Image D
D. Image E
E. Image F

___**A**___**28.** A collection of stars with a very small abundance of heavy elements is shown in

A. Image A
B. Image B
C. Image C
D. Image E
E. Image F

Part II Answer the following four short problems. Each is worth 10 points.

Problem 1: The following is a color-magnitude HR diagram for the star cluster M44



a. (4 points) Calculate the distance to M44

Appendix 1 tells you that M44 is also called the Prasaepe, and it is analyzed in your textbook, Fig. 16-8B. As done in Fig. 13-14 (and as we did in the Pleiades lab) you can use main sequence matching to find $m–M$=5.85=5log$d$–5, so d=148pc.

b. (1 points) Identify the value of B-V at the "turnoff"

The main sequence breaks at $B–V \approx 0.2$

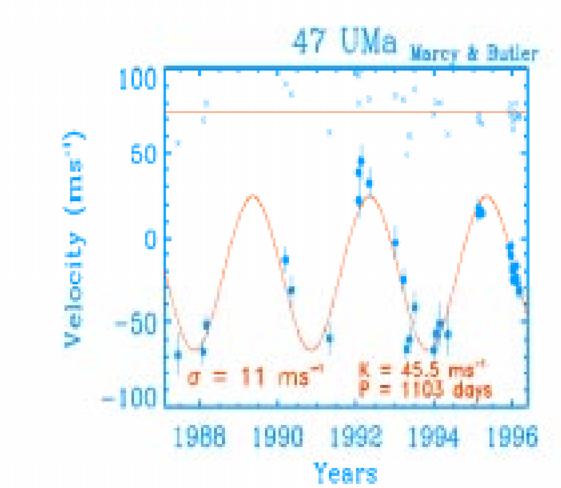
c. (4 points) Calculate the approximate age of M44

From Appendix 4, a star with $B–V \approx 0.2$ has a mass of around two solar masses. These are the stars that are just dying in this cluster, and so gives the cluster age. The lifetime of a star goes something like $M^{-2.3}$ (pg 320) so the cluster age is approximately 10 Billion Years / $2^{2.3}$ = 2 Billion years. This is close enough to Fig. 16-8B which says 0.9 Billion years.

d. (1 point) Which image (*A* through *F*) best represents this HR diagram?

The HR diagram shows a relatively young cluster with some bright orange stars, very much like image *F*. (In fact, *F* is the Jewel Box cluster, not M44.)

Problem 2: The following plot shows data by Marcy and Butler which is evidence for a planet orbiting a star outside our solar system. The star, 47UMa, appears to be very similar to our Sun.



The plot shows Doppler shifted velocities for spectral lines of 47UMa, as a function of the time the observation is made. Marcy and Butler claim this to be good evidence for a "planet" executing a nearly circular orbit around 47UMa.

a. (1 point) What is the orbital period of the planet?

The oscillating curve has a period of about 3 years (in fact, 1103 days=3.02 years).

b. (1 point) What is the evidence that the orbit is circular?

It looks like a sine curve, so the velocity is constant around the whole orbit.

c. (2 points) Estimate the radius of the planet's orbit, divided by the radius of Jupiter's orbit.

We assume 47UMa is just like the sun. Then $P^2=a^3$ where P=3.02 years, and a is in AU, so a=5.20 AU = 0.40 $a_{JUPITER}$.

d. (2 points) What is the orbital velocity of the planet?

$v_{PLANET} = 2\pi a/P$ = 20.6 km/sec where we're actually assuming the planet is much less massive than the star, so that $a \approx a_{PLANET}$.

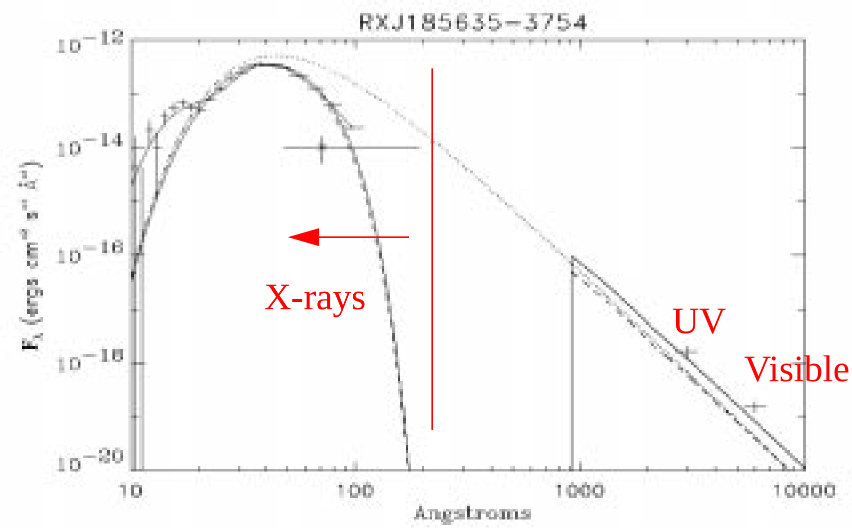
e. (2 points) What is the orbital velocity of the star?

The graph shows the velocity profile of the star, and the amplitude is 45.5 m/sec.

f. (2 points) What is the mass of the planet, divided by the mass of Jupiter?

In a binary system (of which this is an example) the ratio of the velocities of the two companions is the ratio of their masses. (Just from the notion of center of mass, or from the textbook, pg 240. That is $m_{STAR}v_{STAR} = m_{PLANET}v_{PLANET}$ which gives $m_{PLANET} = 4.39\times10^{27}$ kg = 2.31 $m_{JUPITER}$ with $m_{STAR}=m_{SUN}$.

Problem 3: The data shown is from the discovery of an "Isolated Neutron Star" by F. Walter and collaborators. The data points are actual measurements, while the dotted line is the best fit black-body spectrum after correcting for detector response and other effects.



a. (1 points) Clearly indicate on the figure which data points, if any, are radio waves, infrared light, visible light, ultraviolet light, or X-rays.

b. (2 points) What is the photon energy at maximum intensity?

The spectrum peaks at $\lambda = \lambda_{MAX} = 45$ Angstrom = 4.5 nm.

This corresponds to a photon energy $E = hc/\lambda = 4.42\times10^{-17}$ J = 276 eV

c. (2 points) What is the temperature at the surface of the neutron star?

The temperature is given by $T = 2.898\times10^{-3}$ K•m/$\lambda_{MAX} = 6.44\times10^{5}$ K

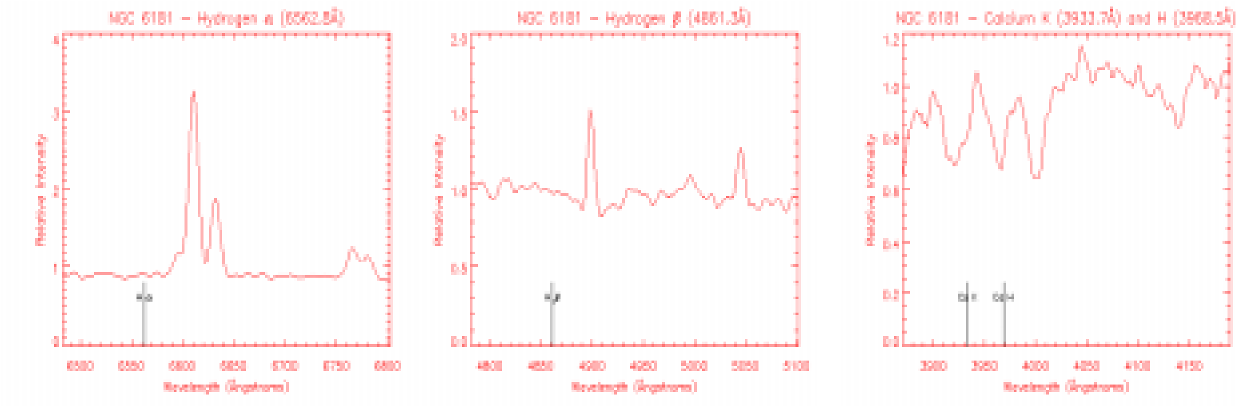
d. (5 points) The area under the blackbody curve is 4.2×10^{-14} W/m^2. Also, the observers can tell that the object is in front of a dark interstellar cloud that is at a distance of 130 pc. What is the maximum possible radius of the neutron star?

The area under the curve is the integrated flux $F = L/4\pi d^2$ where L is the luminosity and d is the distance from the neutron star. The luminosity of a blackbody is given by $L = 4\pi R^2\sigma T^4$ for a blackbody of radius R and surface temperature T. Therefore

$$\frac{R^2\sigma T^4}{d^2} = 4.2\times10^{-14} \qquad \text{where} \qquad d \le 130 \text{ pc}$$

and you can look up σ in Appendix 7. Solving, you find $R \le 8.3$ km.

Problem 4: Shown below are optical spectra of galaxy NGC6181 in three bands which cover the Hα, Hβ, and CaKH regions.The wavelengths for Hα, Hβ, CaK, and CaH lines are indicated.



a. (2 points) What part of the galaxy might emit the Hα and Hβ features?

Hydrogen *emission* can come from star-forming HI regions, or perhaps the central core of an active galaxy.

b. (2 points) What part of the galaxy might emit the CaKH features?

These *absorption* lines come from yellowish G-type stars, probably giants (i.e. old stars) since they are the brightest stars in the galaxy.

c. (2 points) What is the redshift of this galaxy?

All the lines show a consistent redshift. For Hβ, which is unambiguous, you find

$$z = \frac{4900 - 4861}{4861} = 8.0 \times 10^{-3}$$

d. (4 points) What is a reasonable <u>range</u> of possible distances to NGC6181?

The distance to the galaxy is obtained through Hubble's Law:

$$v = Hd \qquad \text{with} \qquad v = zc$$

A range of values comes about because we do not quite know the Hubble constant H, which is somewhere between 50 km/sec•Mpc and 100 km/sec•Mpc. Therefore, the distance to the galaxy is somewhere between 24 Mpc and 48 Mpc.