Astronomy 102: Stars and Galaxies

Review Examination 2

The Real Test Will Not Be This Long.

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 seven questions; each question has equal weight.

Possibly Useful Constants and Formulae

$$R_\odot = 6.96 \times 10^5 \text{ km}$$
$$M_\odot = 1.99 \times 10^{30} \text{ kg}$$
$$T_\odot = 5,600 \text{ K}$$
$$L_\odot = 3.8 \times 10^{26} \text{ W}$$
$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$
$$h = 6.626 \times 10^{-34} \text{ J Hz}^{-1}$$
$$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{K}^{-4}$$

$$1 \text{ pc} = 3.26 \text{ lyr}$$
$$1 \text{ pc} = 206,265 \text{ AU}$$
$$1 \text{ AU} = 1.496 \times 10^{11} \text{ m}$$
$$1 \text{ km} = 1,000 \text{ m}$$

$$f\lambda = c$$
$$E = hf$$

$$L = A\,\sigma T^4$$
$$L = 4\pi R_\odot{}^2\,\sigma T^4$$
$$B = \frac{L}{4\pi d^2}$$
$$\frac{A}{1''} = \frac{1 \text{ pc}}{d}$$
$$\frac{A}{} = \frac{1}{d} \quad A \text{ in } '',\ d \text{ in pc}$$
$$\frac{A}{1\,rad} = \frac{h}{d}$$

Age of Solar System: 4.6×10^9 years

Age of Universe: 13.7×10^9 years

Diameter of Milky Way: $\sim 30,000$ pc

Distance to Andromeda Galaxy: 0.8×10^6 pc

1. Suppose you are desigining a project for Astronomy 222, Observational Astronomy. You want to measure the distance to a near-earth asteroid using parallax. You have two small small telescopes you can use, one at Dyer Observatory (in Nashville) and one in Arizona. The two telescopes are 2000 km away from each other.

You take a simultaneous picture of the astroid from each telescope, and compare the position of the asteroid to background stars. This gives you the angular offset between the asteroid as seen from the two locations to a precision of $2''$.

(a) Draw a picture that shows what you've done above. Indicate on this picture what measurement is 2,000 km. Label with d the distance from the Eearth to the asteroid.

(b) What is the farthest an asteroid can be without being too far for you to measure its distance given the precision of your parallax measurement? (Hint: if you come up with an answer that is measured in parsecs or tenths of parsecs, you've done something very wrong.)

(c) How does your answer in (c) compare to the distance from the Earth to the Moon, and to 1 AU (the distance from the Earth to the Sun)?

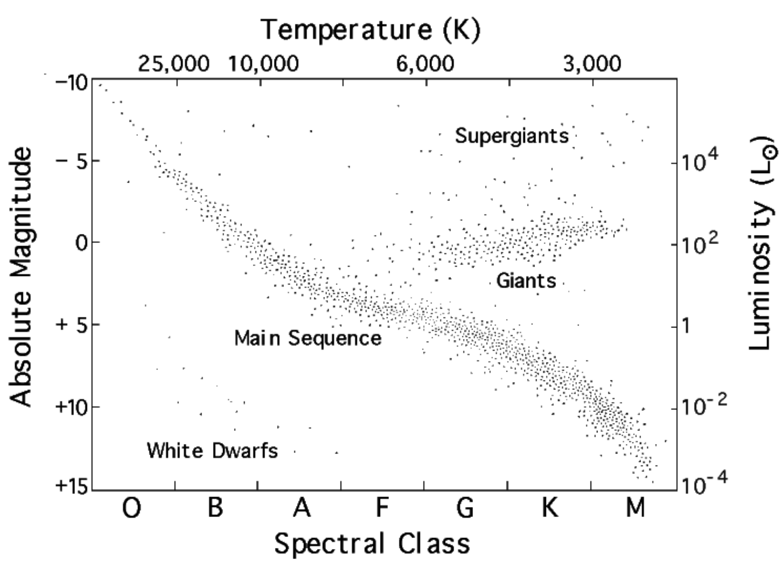
(d) (Bonus.) Where do you want the asteroid to be in the sky as seen from the each observatory so as to make the best possible measurement? (I.e. near rising, near setting, directly overhead, a little east of overhead, or a little west of overhead?) (No, there won't be any "Bonus" questions on the actual test.)

2. You build a gigantic orbiting space telescope with enough resolution that you are able to resolve (measure the angular size of) many stars for the first time.

You pick out two stars of equal brightness to observe. You see that both of them have exactly the same *angular* size.

How do the colors of these two stars compare? Explain how you know.

3. Consider the following H-R diagram:



(a) You observe a star (Star A) that is bluish in color. You measure its spectrum, and find that the spectrum reaches a peak at an ultraviolet wavelength of 1,500Å. What is the temperature and spectral type of this star?

(b) You observe a star (Star B) that is reddish in color. You measure its spectrum, and find that the spectrum reaches a peak at an red/infrared wavelength of 7,800Å. What is the temperature and spectral type of this star?

(c) Star A and Star B have the *same* observed brightness. You measure the parallax of Star A to be $0.0080''$, and the parallax of Star B to be $0.080''$. What is the ratio of luminosities of the two stars?

(d) If you determine that Star A is a main sequence star, what kind of star (White Dwarf, Main Sequence, Giant, or Supergiant) is Star B? Explain.

4. An astronomer want to measure the distance to the Andromeda Galaxy (M31) using parallax. Right now, the best we can measure parallax is to about 1 milliarcsecond ($0.001''$).

(a) [2 points] How precisely (in arcseconds) would an astronomer on Earth need to measure angular distances in order to measure the distance to M31? (I.e. how small an angle would he need to be able to measure well.)

(b) [2 points] Now suppose this astronomer relocates to a space station near Neptune (30 AU away from the Sun). How precisely would this astronomer need to measure angular distances in order to measure the distance to M31?

(c) [2 points] Aside from the expense and trouble of getting a space station out to Neptune, would there be any disadvantage for the astronomer measuring parallax from Neptune? If so, suggest a way that the astronomer, working with colleagues, might get around this disadvantage.

5. [6 points] Star A has a measured parallax of $0.10''$, and Star B has a measured parallax of $0.025''$. Star B appears twice as bright as Star A. What is L_A/L_B, the ratio of the luminosity of Star A to the luminosity of Star B?

6. An astronomer makes the following observations:

- A Cepheid Variable with a period of 10 days has a parallax of 0.022"
- The Cepheid variable is 3.4×10^{-11} times as bright as the Sun in Earth's sky.
- Another Cepheid variable star in a nearby galaxy also has a period of 10 days, and is 1.1×10^{-21} times as bright as the Sun. (This is a very dim star requiring a lot of, for instance, Hubble Space Telescope time to observe!)
- A Type Ia supernova in the same nearby galaxy as the second Cepheid is observed to be 1.5×10^{-15} times as bright as the Sun.
- A Type Ia supernova in another distant galaxy is observed to be 1.3×10^{-19} times as bright as the Sun.

How far away is the more distant galaxy?

HINT: This is a tough problem, tougher than anything I'd ask on the test, but it does take you through a number of things. Perhaps the hardest part is thinking where to start. You can help yourself by working through the following individual questions:

- How far away is the first Cepheid variable?
- How luminous is the first Cepheid variable?
- You know that Cepheids with the same period have the same luminosity; how luminous is the second Cepheid variable?
- How far away is the nearby galaxy?
- How luminous is the Type Ia supernova?
- Type Ia supernovae are "standard candles"; at peak brightness, they all have approximately the same luminosity. How luminous is the Type Ia supernova?
- How far away is the distant galaxy?

7. Consider a cluster of stars all formed at once. This cluster has a typical distribution of stars with mass, i.e. there are only a few high-mass stars ($> 8\,\mathrm{M}_\odot$), but a lot of low-mass stars ($< 8\,\mathrm{M}_\odot$), with lower and lower mass stars more and more common.

Make a plot. On one axis should be *time*, running from $t = 0$ (when the cluster forms) to 100 million years. On the second axis should be a number of stars (using an arbitrary scale). Knowing that high-mass stars live at most a few times 10 million years, draw two lines on your plot. The first line should be the number of *neutron stars* in the cluster as a function of time, the second line should be the number of *white dwarf* in the cluster as a function of time.