July 5, 2005 Name:________________________

Astronomy 102: Stars and Galaxies

Review Examination 3

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 seven questions; each question has equal weight.

Possibly Useful Constants and Formulae

O B A F G K M

Lifetime of 8 $M_\odot$ star: 80 million years.

$$B = \frac{L}{4\pi d^2}$$

$$L = (4\pi R^2)\,\sigma T^4$$

$$1\,\text{Mpc} = 10^6\ \text{pc}$$

$$1\,\text{pc} = 206,265\ \text{AU} = 3.26\,\text{light}-\text{years}$$

$$1\,\text{pc} = 3.086 \times 10^{13}\,\text{km}$$

$$1\,\text{AU} = 1.496 \times 10^{11}\,\text{m}$$

$$1\,\text{km} = 1,000\,\text{m}$$

$$P^2 = A^3 \qquad \text{For } P \text{ in years, } A \text{ in AU}$$

$$P^2 = \left(\frac{4\pi^2}{G\,M}\right) A^3$$

$$z = \frac{\Delta\lambda}{\lambda} = \frac{\lambda_{\text{obs}} - \lambda_{\text{orig}}}{\lambda_{\text{orig}}}$$

$$z = \frac{\text{Size Now}}{\text{Size Then}}$$

$$z = \frac{v}{c} \qquad \text{For } v \ll c$$

$$z = \left(\frac{H_0}{c}\right) d \qquad \text{For } z \ll 1$$

$$z = H_0\left(\frac{d}{c}\right) = H_0\,t \qquad \text{For } z \ll 1$$

$$v = H_0\,d \qquad \text{For } v \ll c$$

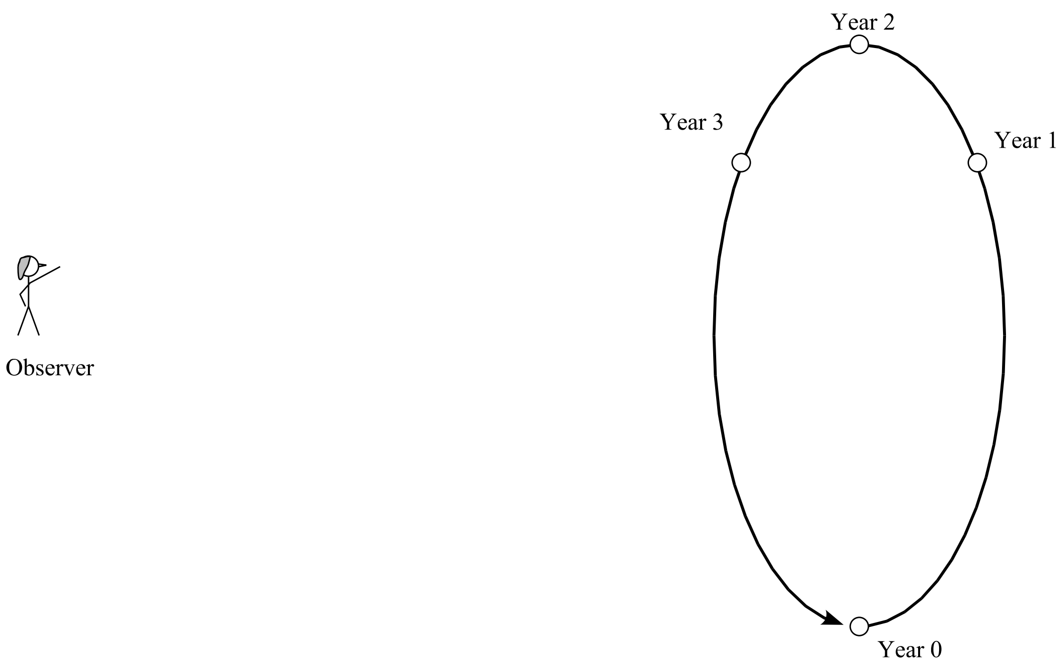
$$c = 3 \times 10^5\,\frac{\text{km}}{\text{s}} = 3 \times 10^8\,\frac{\text{m}}{\text{s}}$$

$$H_0 = 71\,\frac{\text{km/s}}{Mpc}$$

$$A = \frac{h}{d} \qquad (A \text{ in radians, } h \text{ and } d \text{ in the same units})$$

1. Consider a binary system with an elliptical orbit; one star in the binary is more massive than the other. Below is drawn the ellipse that is the orbit of the *less massive* star. The less massive star's orbit takes four years to complete; its position at the beginning of years 0, 1, 2, and 3 are shown on the digram. (By year 4, it's back where it started.)

While the drawing shows the binary system looking down on it's orbit (face-on), an observer (shown to the left of the page) observes this system edge on.



(a) Draw the orbit of the more massive star in the binary on the diagram above, including an arrow that indicates the direction of motion. Draw and label four spots that indicate the position of the more massive star at each of year 0, year 1, year 2, and year 3.

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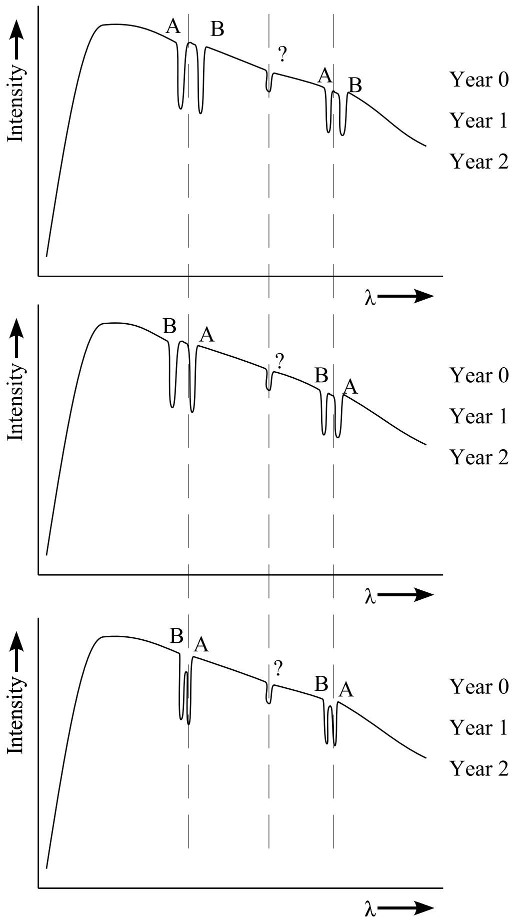
1. (Continued)

To the right are four spectra taken by the observer drawn on the previous page; the observer used a space telescope to take these spectra. The spectra include the light from *both* of the stars. The absorption lines labelled A come from one of the stars in the binary system, and the absorption lines labelled B come from the other. (The "?" line is a mystery absorption line which you can ignore for now.) The dashed vertical lines drawn through the four spectra indicate the rest wavelengths of each line.



(b) Is Star A or Star B from the spectra to the right the *more* massive star in the binary system? Explain.

(c) For each spectrum, circle the time at which this spectrum was taken (Year 0, Year 1, or Year 2).

(x) **Extra credit– 1 point** Explain where the mystery line is coming from.

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2. **(a)** Make a sketch of two rotation curves (orbital speed as a function of distance from the center). Make sure to label your axes, and which curve is which. One rotation curve should be for Keplerian orbits, i.e. orbits that obey a $P^2 \propto A^3$ law. The second should be the one observed in the Milky Way.

(b) Is the matter in the Milky Way *more centrally concentrated* or *more spread out* than matter that would lead to Keplerian orbits?

(c) Sketch the rotation curve of a merry-go-round (that is, the rotation of a rigid disk).

(d) To get a merry-go-round-like rotation curve from gravitational orbits, would you need matter that is *more centrally concentrated* or *more spread out* than the matter is in the Milky Way? (Note that it is *not* gravity that holds a real merry-go-round together, but rather molecular forces.)

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3. One type of standard candle used by astronomers is Type Ia supernovae. A Type Ia supernova (SN Ia) has a luminosity of $5.8 \times 10^9\, L_\odot$ at maximum light; it is this high luminosity that makes them visible to such great distances.

(a) You discover and observe a supernova in a distant galaxy. In your telescope, you observe it to have a brightness that is 1.6×10^{-7} times the brightness you observe for Vega. How far away is this galaxy (in Megaparsecs (Mpc))?

(b) You measure a redshift for this galaxy of $z = 0.062$. Using just the data from this galaxy and this supernova, what would you calculate the expansion rate of the Universe to be?

(c) If a second supernova explodes in this galaxy 200 million years after the supernova you observed, how long from now *or* how long ago does this second supernova explode? (Be sure to indicate whether it happens in the future or the past.)

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4. Stars are held in equilibrium by the conflict of gravity and motion (pressure). Give two examples from stellar evolution evolution of cases where either gravity or pressure wins, at least for a short while. For each case, explain how one or the other wins, and describe what happens.

5. Sketch a plot. The horizontal axis should be time, going from zero to 160 million years. The vertical axis should be number of stars.

Consider a star cluster. Draw two curves (clearly labelled) on your sketch. The first should be the number of neutron stars present in the star cluster. The second should be the number of white dwarves present in the star cluster. (Don't worry about scaling the absolute heights of the lines together. In other words, the range of the y-axis can be different for the neutron star line and the white dwarf line.)

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6. Binary stars generally form together, at the same. Tatooine (Luke Skywalker's home planet) orbits a binary star system; both stars are approximately the same luminosity. One is orange, one is blue.

(a) Suggest at what stage of stellar evolution each star must be to match this description. Which star must be more massive?

(b) As depicted in *Star Wars*, the two stars appear the same size to Luke, and are also about the same brightness. Is this realistic? Justify your answer.

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