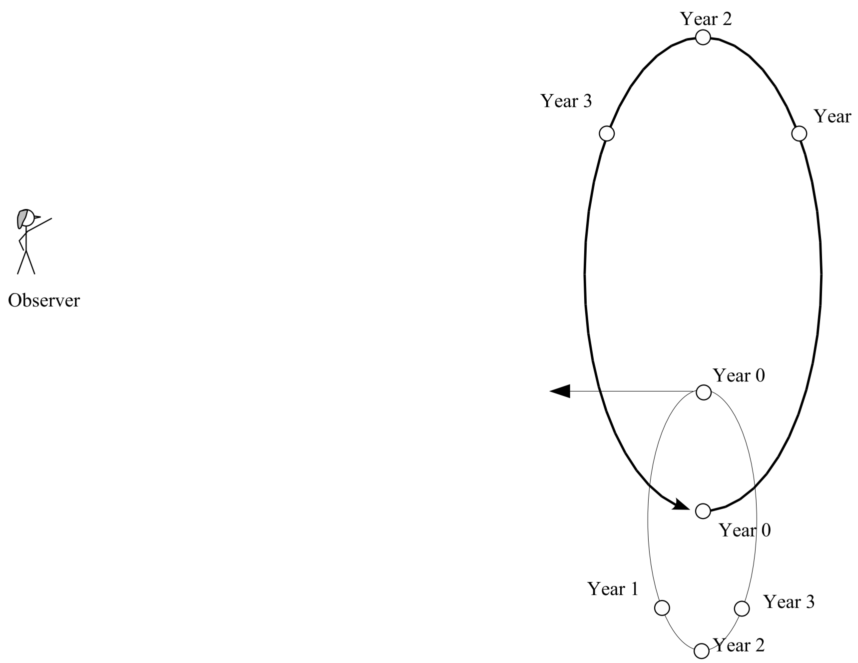
Astronomy 102, Fall 2004

Exam 3 Solutions

1. (a)



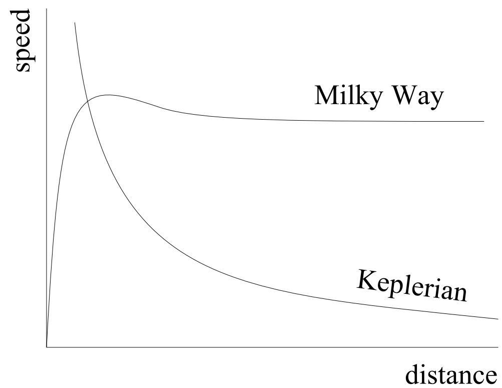
(I also accepted answers where the massive star's ellipse was fully nested inside the other one, as long as it was offset in the right direction and the points were clustered properly.)

(b) Star A is. It's lines show less of a blueshift or redshift than Star B— the lines are always closer to the rest wavelength for that line. The star that is more massive is going to be the star that shows slower motion.

(c) First diagram: Star A is approaching relatively quickly. That's Year 0. Second diagram: Star A is receeding relatively quickly: that's Year 2. (Really it should be moving slower than than it is at year 0.) Third diagram: Star A is approaching with a much lower velocity, barely resolved from Star B. That actually doesn't happen at any of the four times indicated. (It happens between years 0 and 1, and between years 2 and 3). Fourth diagram: Star A is receeding with a much lower velocity. That happens at both years 1 and 3. (Most of the velocity of Star A there is across the sky, with only a small component along the line of sight.)

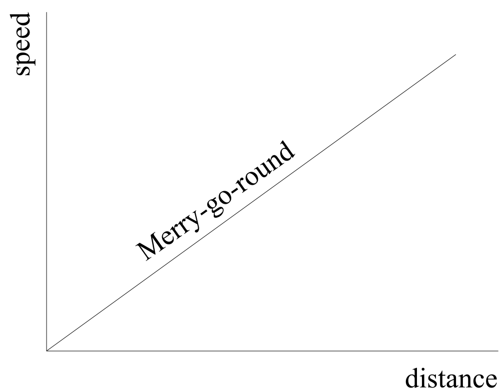
(x) An intervening cloud of gas between the binary star system and you.

2. **(a)**



(b) More spread out. Matter in the Milky Way we know is spread out, whereas in a Keplerian system (like the Solar System) it's all right at the center. Another way to think about this is that in the Milky Way case, you have objects moving faster farther out than you do in the Keplerian case. That means that as you get farther out, you need more and more mass closer to the center holding that matter in so it doesn't fly off. This naturally leads to a spread out mass distribution, as you need more and more mass as you get farther and farther out.

c In a merry-go-round, the *period* is constant. A point on the disk twice as far out has twice as far to go (the circumference of the circle it makes is twice as large), but it does it in the same amount of time. This means that the velocity is proportional to the distance:



Whereas Keplerian has decreasing velocities and the Milky Way has constant velocities as you get farther and farther from the center, this has ever-increasing velocities. That means that if you want to get this rotation from a gravitational system, at large distances you need proportionately even more mass to create gravity and hold the stuff in, so this would be a mass distribution more spread out than even the Milky Way.

(Note that in a real merry-go-round, it's not gravity that holds it together against the tendency of the molecules to want to fling apart from each other; its the molecular bonds and forces between the molecules that hold it together.)

3. **(a)** Most of the first batch of planets found were very large (Jupiter sized or larger) and very close to their star (closer than the Earth is to the Sun).

(b) It would seem to suggest that the theories are wrong. The theories match our solar system, but don't match these other planets.

Yet, astronomers still believe those theories. How to reconcile this? Current modeling suggests that when planets form, drag forces between the planets and the other left over junk in the protoplanetary disk can cause a planet to migrate in to smaller orbits after it has formed. This means that gas giants can form far away where things still work, and then after they've formed move in close to the star where we often (though not always) observe them.

(c) We discovered the planets by observing the Doppler effect of the parent star wobbling back and forth. A larger shift in the star's lines would be easier to observe, so you need a maximum wobbling of the star. You're going to have the greatest gravitational force on a star from a planet that is both large and close— so the observational methods meant that we would find large and close planets first, just because they were easiest to find.

4. (a) We're in a very special place. The Dark Energy is spread uniformly throughout the Universe. Dark Matter is found only in galaxies, which is why there is more Dark Matter in your hands than Dark Energy, even though Dark Energy is more common in the whole Universe. Similarly, normal matter is concentrated down in the disks of galaxies, whereas Dark Matter is much more spread out. Even more, our planet and its atmosphere is a very dense little clump of normal matter.

We're at a place where the normal matter really congregates, and even at a place where dark matter sort of congregates. This is why what we see in our hands is at odds with what's in the Universe averaged over everything.

(b) This would seem to contradict! We just said that we're in a special place, which is why we see different densities from the Universe averages.

However, the cosmological principle can be saved if you realize that our galaxies is just like billions of other galaxies out there, and our star is just like billions of other stars out there. We may be in a good place for life, but it may be pretty typical of the sort of planet that can be found around countless stars in countless galaxies, meaning that really, in the end, we're nowhere special.

5. (a)

$$\frac{B_{\rm SN}}{B_V} = \frac{\frac{L_{SN}}{4\pi\, d_{SN}{}^2}}{\frac{L_V}{4\pi\, d_V{}^2}}$$

$$\frac{B_{\rm SN}}{B_V} = \left(\frac{L_{SN}}{L_V}\right)\left(\frac{d_V}{d_{SN}}\right)^2$$

$$d_{SN} = \sqrt{\left(\frac{L_{SN}}{L_V}\right)\left(\frac{B_V}{B_{SN}}\right)}\, d_V$$

$$d_{SN} = \sqrt{\left(\frac{5.8\times 10^9\, L_\odot}{55\, L_\odot}\right)\left(\frac{1}{1.6\times 10^{-7}}\right)}\,(7.8\,{\rm pc})$$

$$\boxed{d_{SN} = 200,000,000\,{\rm pc} = 200\,{\rm Mpc}}$$

(b) Expansion rate is H_0. We have:

$$H_0 = \frac{v}{d} = \frac{c\,z}{d}$$

$$H_0 = \frac{(3\times 10^5\,{\rm km/s})(0.062)}{200\,{\rm Mpc}}$$

$$\boxed{H_0 = 93\,{\rm km\,s^{-1}\,Mpc^{-1}}}$$

(This value is different from the best astronomically measured value of $72 \pm 7\,{\rm km\,s^{-1}\,Mpc^{-1}}$.)

(c) The constant-expansion-rate age estimate for the Universe is the Hubble Time:

$$t_H = \frac{1}{H_0}$$

$$t_H = \left(\frac{\rm s\ Mpc}{93\,{\rm km}}\right)\left(\frac{3.086\times 10^{13}\,{\rm km}}{1\times 10^{-6}\,{\rm Mpc}}\right)\left(\frac{1\,{\rm year}}{3.156\times 10^7\,{\rm s}}\right)$$

$$\boxed{t_H = 1.1 \times 10^{10}\text{ years} = 11\text{ billion years}}$$

(d) It's 200 million parsecs away, which means it's (200×3.26) million light-years away, or 650 million light-years away (to two significant figures). This means that the supernova we saw actually exploded 650 million years ago, so the second supernova must have exploded $\boxed{\text{450 million years ago}}$. (We won't see it ourselves for another 200 million years, if we live that long. The history of species endurance on Earth suggests that 200 million years is a mighty optimistic estimate.)