AST 301, Fall 2015 **Introduction to Astronomy**

Comments on Homework 6
Part A

A1. **b.** At optical wavelengths dust in the disk of the Galaxy is a serious problem. Roughly, light is cut by 50% for every thousand parsecs. At longer wavelengths - say in the infrared - the dimming by dust is much less severe and the center of the Galaxy is observable.

A2. **c.** The key aspect of the period-luminosity relation (see Seeds Figure 12-14) is that it is a tight or narrow relation between period and luminosity. A secondary aspect is that luminosity increases with period. A decreasing or a flat period-luminosity relation (see Q3) would serve almost equally well.

A3. **a**

A4. Seeds page 329 says the orbital period of the Sun is 225 million years. Then, the number of orbits is 5 billion years divided by 225 million years = 0.225 billion years = 22 orbits. For an alternative way to do this calculation, see A16.

A5. The period-luminosity relation tells us that the 10 day Cepheid is less LUMINOUS than the 100 day Cepheid. Since the former is less luminous yet brighter, it must be closer than the 100 day Cepheid. (Brightness proportional to luminosity divided by distance-squared.)

A6. **c**

A7. **a**

A8. Type II SN come from massive (i.e., short-lived) stars and were formed recently from interstellar gas clouds. But elliptical galaxies have no gas and thus cannot form new stars and fresh Type II SN. Supernovae seen in elliptical galaxies are all Type Ia SN, that is exploding white dwarfs where the white dwarfs have come from low mass (i.e., log-lived) stars and, in particular, from binary stars where the companion may take a very long time to transfer mass to the white dwarf and increase its mass to the critical Chandrasekhar mass limit.

A9. **b**. See Seeds p.402

A10. Hubble expansion of the Universe is described by the relation velocity of recession = Hubble constant times distance. Rearranging this, we get D = V/H_0 = 6000 [km/s] / 50 [km/s/Mpc] = 120 [Mpc]. Distances to galaxies are very often quoted in mega-parsecs, as here. Sometimes it's illuminating to give distances in light years so as to be able to cite a look-back time in years. For such a conversion, recall that a parsec is 3.26 light years.

A11. **d.** What would your answer be if the question asked about the Sun's central core instead of the atmosphere?

A12. **c**

A13. **b**. Think look-back time and subtract that time from the age of the Universe.

A14. See Seeds p. 375

A15. Consider the line drawn through the points. Take a point on that line: say V = 1000 km/s and D= 2 Mpc which combination gives us a Hubble constant of 1000/2 = 500 km/s/Mpc.

A16. The orbital period is the length of the orbit divided by the orbital velocity. Part of the challenge is keeping track of the different units. For a circular orbit of radius R the length (circumference of the circle) is L = 2 x pi x R. Hence, the time taken to complete an orbit is L/V. In this case, L = 6.3 x 4000 [pc] = 25000 x 3.1 x 10^(13) [km] and t = L/150 [s] = L/150/3.2 x 10^7 [yrs] which corresponds to t = 160 million years.

Part B

B1. **a.** Radial velocities are determined from a spectrum of a galaxy. Characteristic absorption (or emission) lines are identified and their wavelength (redshift) shift relative to their laboratory wavelength is measured. This shift via the formula for the Doppler effect gives the radial velocity. Seeds Figure 18-4 p.394 illustrates this idea.

Determination of distances to galaxies is more involved. We need to describe the idea of a distance ladder: trig. parallax --> spectroscopic parallax and Cepheids in open clusters --> period-luminosity relation for Population I Cepheids --> Type Ia supernovae's peak luminosity from SN observations of Cepheid-containing galaxies --> in more distant galaxies search for Type Ia SN and assume peak luminosity is same as in previous sample.

b. No - See Seeds pp. 393-394

c. See Seeds p/ 395 and the formula t = 10^(12)/H_0 years. If H_0 = 200 km/s/Mpc, the expected age of the Universe is 5 billion years but the stars in globular clusters are around 12 billion years. Either we are lacking in our understanding of stars in the clusters, the Hubble constant has been overestimated or the Big Bang model of the Universe is appropriate (think, for example, steady-state Universe).

B2. **a.** See Seeds pp. 323-326. In particular, see Figure 15-4 where the inset will show that Shapley's determination was not terribly precise.

b. Briefly describe either the top-down and/or the bottom-up model for the Galaxy's formation (Seeds pp. 342-344) to answer this part.

c. The globular clusters would be uniformly distributed over the sky in contrast to the present concentration towards Sagittarius. The open clusters could be distributed roughly uniformly in a ring corresponding to the Galactic disk. Thanks to the dust in the disk, we would in visible light see only the nearest open clusters. At infrared wavelengths, we should see almost through the disk and all of the clusters.

B3. **a**. See Seeds p.324
b. Type Ia SN are used -see comments on B1a
c. See Comments on Q3 and B2a

B4. **a.** See Seeds pp.353-356, especially the double=page spread p.354 and p.355 Oddly, Seeds does not show Hubble's tuning fork diagram but you may Google the diagram - see, for example, https://en.wikipedia.org/wiki/Hubble_sequence
b. E to Spirals: very improbable because Es lack gas (and dust) but Ss are rich in gas (and dust). How does a system of stars but no gas generate a lot of gas? Spirals to elliptical: also improbable because the spirals' oldest stars and as old as though in ellipticals.

B5. **a.** See Seeds for a statement of the cosmological principle -also A9 above. The perfect cosmological principle replaces the phrase `at a given time' with the phrase `at all times'.
b. Since the Universe is observed to be expanding, an insistence that the Universe appear the same on a large scale to all observers at all times leads to the requirement that matter be created continuously at such a rate that the spatial density of galaxies remain the same in the expanding Universe.
c. See comments above on B1c

B6. **a.** See Seeds p.380. Discuss their full name `quasi-stellar radio sources'. Often referred to as QSOs and some QSOs are radio sources (`radio loud') and some are not (`radio quiet'). The brightness - red shift connection shows that they are very luminous.
b. For many QSOs, brightness varies appreciably on a time scale of a few days. Such an observation tells us that the size of the volume from which QSO light is coming from is a few light days across. Think of a cluster of light bulbs with the bulbs being turned on and off at random. The time delay between the nearest bulb being turned off (or on) and the most distant one being turned on (or off) will be the time it takes light to travel across the separation between the two bulbs.
c. Images of QSOs, especially the nearer ones, show light coming from a surrounding area which in deep exposures looks like a galaxy. This are and the QSO have the same redshift.