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

Comments on Homework 5
<u>Part A</u>

A1. The maximum mass for a white dwarf is set by the Chandrasekhar limit at 1.4 solar masses. For a neutron star, the maximum mass is believed to be between 2 and 3 solar masses. There is no maximum mass or a black hole. Thus, answer is b

A2. The AD 1054 event was the appearance of a supernova. At that location, there is now an intriguing object called the Crab nebula, the supernovas's remnant (see Seeds pp. 288-290, Fig. 13-17). In the nebula, a pulsar has been detected and pulsars are considered to be neutron stars. Thus, the answer is d.

A3. The Sun, as a red giant, will shed its outer envelope and expose its hot C-0 core which will cool to become a white dwarf

A4. Collapse leads to the surface gravitational field increasing strongly. Collapse results in the surface being closer to all the mass of the star and since gravitational force increases with decreasing distance to mass, the surface field increases

A5. **b.** See seeds p. 309. The radius is 3 km for each solar mass of material making up the black hole.

A6. Low-mass main sequence stars are cool objects. Cool objects (assumed to emit like black bodies) emit most of their radiation at long wavelengths (that is red to infrared wavelengths) and VERY little in the ultraviolet Thus, and infrared telescope. See Wiens's law.

A7. The Sun's evolutionary track will connect: main sequence star-→ red giant → planetary nebula → white dwarf→ black dwarf. Black dwarf is not commonly used in professional circles. White dwarfs are born hot but have no way to generate fresh energy. All they can do is cool and so run down their internal source of energy/heat. Eventually they exhaust the internal energy and are very cold objects which emit very little radiation, that is they appear 'black'.

A8. The 20 solar mass star's evolutionary track will connect: main-sequence star→ Cepheid variable→ red supergiant→ Type II supernova→neutron star or a black hole

A9. See A1

A10. In a very young cluster, the brightest stars will be 0 and B type main sequence stars or blue ad even red supergiants. See, for example, Figure 12-7 which shows the evolutionary track of a 15 sola mass star drawn at roughly constant luminosity from spectral types 0 to M Of course, the brightest blue and the brightest red stars will be different stars. In a very old cluster surviving main sequence stars will be of low mass. Star evolved off the main sequence have become red giants which will be the brightest stars in the cluster.

A11. An example of the method of spectroscopic parallaxes. Pick any spectral type: say B. In cluster alpha B stars have a brightness of 10 and in beta a brightness of 1/1000. Thus, main sequence stars of a given spectral type in beta are 10,000 times fainter than their counterparts in alpha. Knowing that brightness scales are 1/distance-squared, we find that beta is 100 times more distant than alpha. Distance of beta is 200 times 100= 20,000 parsec.

A12. **b**.

A13. 'contains dust that obscure tits distant regions'

A14. globular clusters

A15. **b.** Lifetimes of main sequence stars scale as 1/mass-cubed. High mass→ short lifetime. Lower mass → longer lifetime. If the main sequence has been eaten away down to F2 (lower mass than B2), the cluster is older.

A16. Galaxy→ kiloparsex→ light year→ Betelgeuse → white dwarf→ 50 solar mass black hole→ neutron star→ kilometer→ centimeter→ hydrogen atom→ atomic nucleus
The Schwarzschild radius (see A5) increases by 3 kms. for every solar mass of material. A 50 solar mass black hole has a radius of 3 x 50=150 kms.

A17. Sirius A is an A-type main sequence star and Sirius B is its white dwarf companion. The Crab pulsar is a neutron star. For the four astronomical objects, the sequence of increasing average density is Betelgeuse→ Sirius A→ Sirius B→ Crab pulsar. This leaves classroom air in competition with Betelgeuse. Atmospheric density at sea level and 15C is 0.001225 gram/cm-cubed. (Check my calculation!) It's clear then that Betelgeuse's average density is almost a thousand times smaller than that of the air in our classroom. Knowing that the core of the star is dense, the density of Betelgeuse's atmosphere is Very much smaller than the classroom air.

Part B

B1. a. See Seeds p. 275
b. The lifetime of main sequence stars increases steeply with decreasing mass: lifetime scales a 1/mass-cubed. Given that the lifetime of the Sun is 10 billion years, the lifetime of a 0.4 solar mass star is 10/0.4 – cubed = billion years. BUT the age of the Universe is just 14 billion years. In sot 0.4 solar mass main sequence stars, even from the first generation of stars have had no reason to evolve off the main sequence.

c. White dwarfs have low luminosities and would have to be VERY close to be among the brightest stars in the sky. Even though common, there are none so close. Consider, for example, the very bright star Sirius which has a white dwarf companion. Sirius A is the brightest star in the sky and at about 3 pc from us. Sirius B, the white dwarf, is about 100 times too faint to make the list of stars visible t the naked eye. So, the white dwarf would have to be ten times closer to make the list, that is within 0.3 pc or light year.

B2. a. Type II SN show H- lines in their visible spectra. Type Ia SN do not show H-lines. Type II SN come from massive stars and are found in the disk of spiral galaxies. Type Ia SN come from exploding white dwarfs. Type Ia galaxies tend to be found outside the disks of spiral galaxies and in elliptical galaxies (Type II SN are not found in elliptical galaxies).

b. Clearly, you need to observe routinely a large sample of spiral galaxies in order to detect a few supernovae in a reasonable period of time. Given that supernovae reach peak brightness rapidly and fade relatively slowly (see Seeds Fig. 13-15), you should look at galaxies in your sample about once a week. This exercise could be done just by visual inspection. Indeed, it has been done- just check Robert Evans (Astronomer) on Wikipedia.

c. dust

B3. See Seeds

B4. a. See Seeds

b. See the lighthouse model of pulsars- Seeds pp. 300-301.

c. Neutron stars are supported by degenerate neutrons. But before the mass of neutron star reaches it equivalent maximum mass to the Chandrasekhar limit for white dwarfs, neutrons are broken apart in their constituent parts known as quarks. Our understanding of the forces binding the three quarks into a neutron is incomplete. Best estimates result in the mass range of 2-3 solar masses for the maximum mass of neutron star. This is pretty well confirmed by measured masses for neutron stars.

B5. a. Neutron star and black hole. See Seeds for descriptions.

b. See seeds for why 'final'.

c. Discuss how gas immediately outside the black hole is heated-see Seeds. Note how an isolated black hole is effectively undetectable. A companion star is needed in order to supply gas to the black hole. Discuss the accretion disk. To discriminate between a neutron stat and a black hole as the object inside the accretion disk, one must determine the mass of this object. This demands detailed analysis of he binary system containing the object and the star feeding the accretion disk.

B6. a. See Seeds. 'Metal" in astronomy means all elements from carbon and heavier. Dome author would include too LI, Be and B the light elements between He and C in the periodic table. Metal- poor refers to mixtures which are 1/10 or less tha metal content of the Sun.

b. Again the answer is tied to the facts that

(i) main sequence stars have lifetimes which scale as 1/mass-cubed and

(ii) metals are made by stars which return some of their products to interstellar gas from which a new generation of stars is formed and so over time the metal content of the gas and new stars increased. M type main sequence stars have such low masses that their lifetimes (see B1b) exceed the age of the Galaxy (and Universe). Early generation of these stars were meal-poor but are still around. Recent and current generations are metal-rich and are still around too. By sharp contrast, 0-type main sequence stars have VERY short lifetimes and only the most recently formed examples are observable and these are metal- rich.

c. Metal- content is roughly correlated with the age of the population. Supernova remnants are rich in metal. Technetium- no stable forms- is detected in some red giants showing that such stars are manufacturing Tc and other heavy elements.

B7. a. See Seeds p. 212

b. To detect rotation one employs-of course- the Doppler shift. And for spiral galaxies one uses the 21-cm line of neutral hydrogen. Consider, first a galaxy seen edge- on. One would point the radio telescope at one side the galaxy and at different positions from the center record the wavelength of the 21-cm line an thus measure the Doppler shift and calculate the radial velocity. For the edge-on galaxy, this radial velocity would be the rotation velocity of the galaxy. In this way, you would map out the rotation velocity as a function of distance out from the galaxy's center. One side of the galaxy would show radial velocities of approach and the other side velocities of recession. For a face-on galaxy, this approach would not work-Why?

c. The rotation of the two galaxies would differ depending on how the dark matter was distributed in the galaxy. Seeds p. 329 and Fig. 15-10 illustrates the rotation curve of our Galaxy- its what we call a flat rotation curve – see also Seeds Fig. 16-7. In general, a flat rotation curve is a signature of a dark matter-dominated galaxy. In a galaxy without dark matter, we would expect the light to trace the matter and for the many galaxies showing light to be concentrated in their center, the rotation velocities will decrease sharply with increasing distance from the center. This is what we call Keplerian motion. fitted through the Sun's positon.