You may use one sheet of notes. You may not use books or additional notes.

Do the easy questions first. Then go back to the harder ones.

The spectral classes are O, B, A, F, G, K, and M in order of decreasing temperature.

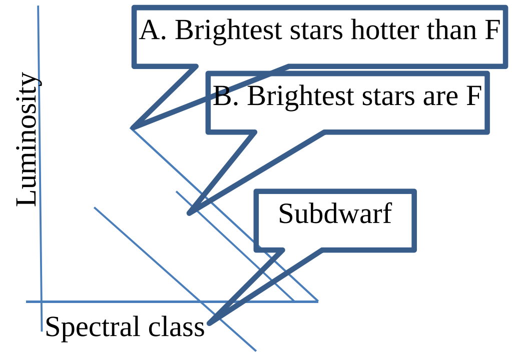
Name	
PID	
1	/ 9
2	/ 4
3	/ 6
4	/ 9
Total	/ 28

1. Star cluster A is 5 billion years old and star cluster B is 10 billion years old. Stars of spectral class F are the hottest main sequence stars in cluster B. You must explain your reasoning to receive any credit.

   a. (2 pts.) Sketch the Hertzsprung-Russell diagram of the main-sequence stars (also called dwarfs) of cluster B.

   b. (3 pts.) Sketch the H-R diagram of the dwarfs of cluster A on the same diagram. Assume the measured distance of cluster A is less than its true value.

   Since Cluster A is younger, it has hot stars that have already died and disappeared in cluster B. Since the measured distance is less than the true value, its stars are brighter than their true value.



   c. There is a type of star called a sub-dwarf, for which the radius is ¼ that of a dwarf of the same temperature. (Sub-dwarfs have much less of the elements heavier than helium than do dwarfs.) (1 pt.) Sketch the location of the sub-dwarfs on your H-R diagram. (3 pts.) How many magnitudes are sub-dwarfs shifted from dwarfs of the same temperature?

   Use $L = R^2T^4$. Because the radius is ¼, the luminosity of a sub-dwarf is 16 times fainter than a dwarf. The magnitude is shifted by a bit more than +2.5mag. More precisely, the magnitude is shifted by $2.5 \log 16 = 3.0$mag.

2. (4 pts.) Prof. Balter Adams of the University of Michigan found two stars, A and B, that are very close together in the sky in the constellation Canis Major. He determined the spectral classes of the two stars and found them to be the same. Star B is 15 magnitudes fainter than star A. Prof. Adams says he discovered a new type of star that is fainter than white dwarfs. Has he discovered a new type of star? Explain.

   The clues are very much like Walter Adams' discovery that Sirius B is a white dwarf. However, there is a crucial missing clue. Since Sirius A and B were known to orbit each other, they must be at the same distance. Balter does not know that his two stars are at the same distance. It is likely that B is faint because it is farther from us.

3. There is a black hole in the center of the Milky Way galaxy with a mass 1 million times that of the sun. Stars have been observed to move around the black hole.

   a. (3 pts.) What are the possible shapes of the orbits of the stars? You must explain your reasoning to receive any credit.

   Newton showed that Kepler's Laws apply for the case of an object orbiting an object with a much larger mass. Therefore Kepler's1st law applies. A star orbits the black body in an ellipse with the black hole at one focus.

   b. (3 pts.) A star has been observed to orbit at a distance of 100AU. How long does it take to complete one orbit? (Assume the orbit is circular for this calculation.)

   Kepler's 3rd Law as stated by Newton is $P^2 = R^3/M$. $P = \sqrt[2]{\frac{100^3}{10^6}} = 1$year

4. The satellite Hipparcos measured parallaxes of a hundred thousand stars by measuring their positions over the course of several years. (Hipparcos orbits earth close to earth.) The change in right ascension of stars A, B, and C is shown in the plot.

a. For star A, answer these questions: (2 pts.) Why is the right ascension changing? You must give reasons. (1 pt.) What is its distance? If it is not possible to find its distance, explain why.

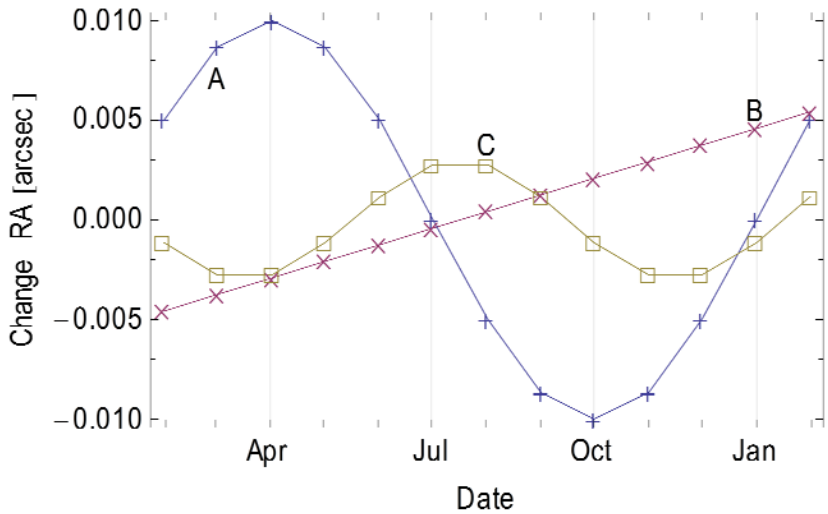


Figure 1 Change in right ascension over a year for stars A-C.

For star A, the right ascension changes as a sine function with a period of 1 year. As Earth (and Hipparcos) moves around the sun, the baseline changes sinusoidally. Therefore the position of the star moves because of parallax. The distance $D = \frac{B}{a} = \frac{1}{.01} = 100\text{pc}$.

b. Answer the same questions for star B.

For star B, the position changes linearly. The star is really moving. Since the motion is not sinusoidal with a period of a year, there is no information about distance.

c. Answer the same questions for star C.

For star C, the motion is sinusoidal, but the period is less than a year. Therefore the motion cannot be due to parallax. The star is likely to be in orbit around something unseen. Since no parallax is seen, the distance cannot be determined.