AY C10/L&S C70U **Name:** ____________________

Fall 2018

Worksheet 6

10/14/2018

This worksheet covers the Sun and the stars. There are 4 pages (including this cover page) and 2 questions. Accuracy is definitely desired, but effort and clear physical reasoning are far more important than the final answer.

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1. In this problem, you will answer a variety of short questions about the Sun, stars, and star formation.

   (a) The luminosity of the Sun $L_\odot = 3.828 \times 10^{26}\,\mathrm{W}$, while the human eye's pupil has a radius of $0.2\,\mathrm{cm}$. If the weakest signal the human eye can discern is 100 photons/s, **compute the greatest distance from Earth** at which an exact copy of the Sun would be visible with the naked eye. As a simplifying assumption, assume that all of the star's light is emitted as $500\,\mathrm{nm}$ photons.

   (b) The luminosity of a star typically scales with its mass as $L \propto M^4$. Use this scaling relation to answer the following subparts:

      i. **Estimate the luminosity** of a star of $3M_\odot$.

      ii. Throughout its main-sequence lifetime, a star will burn approximately 10% of its initial mass. This process will give the Sun a main-sequence lifetime of approximately 11 billion years. **Derive a scaling relation** for stellar lifetime, and use it to **estimate** the lifetime of the $3M_\odot$ star.

2. A *Hertzsprung-Russell diagram* (HR diagram) plots the temperature and luminosity of a list of stars. Use the HR diagrams below to answer the following questions:

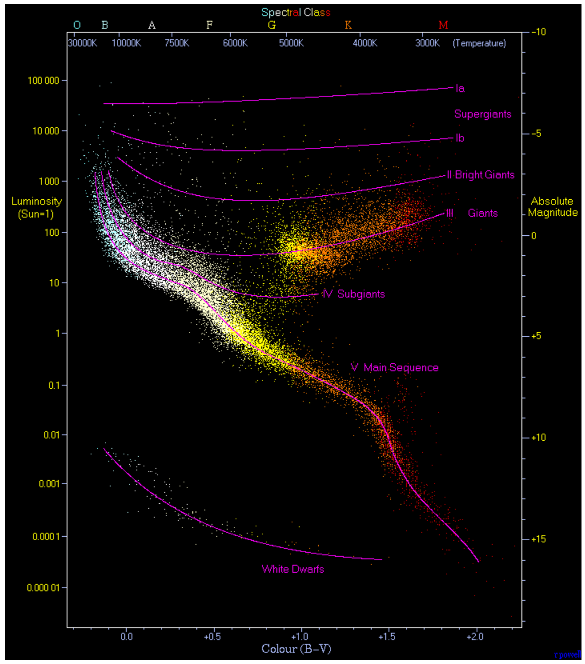

Figure 1: The HR diagram for the all-sky *Hipparcos* survey.

(a) **Briefly explain** the significance and characteristics of O, B, A, F, G, K, and M spectral types. There is no need to go into detail on each one; just discuss general trends.

(b) Stars of more than 2 $M_\odot$ have short enough lifetimes that within the age of the Universe, there have been many stages of star formation and death. Approximately 15% of such are observed to be giants. **Explain briefly** why this is the case.

(c) As the Universe grows older, **what would you expect** to happen to the number of stars on the white-dwarf branch?

(d) The probability of a star forming on the main sequence at a particular mass is given by $\eta(m) = Am^{-2.35}$, so in principle we would expect most of the stars we observed to be on the lower-mass, lower-luminosity end of the spectrum. **Why, then,** does the *Hipparcos* HR diagram have more stars at high mass and high luminosity? **Justify** using a scaling argument. *(Hint: generalize the result about farthest detection distance of Sunlike stars.)*

(e) We can construct HR diagrams not only for the whole sky, but for individual star clusters as well. In the following subparts, we qualitatively analyze the following HR diagram for a single star cluster. *(Note: The x-axis represents a color index [an observational proxy for temperature] for temperature whereas the y-axis represents the luminosity in absolute magnitude. How they translate to one another is beyond the scope of this course.)*

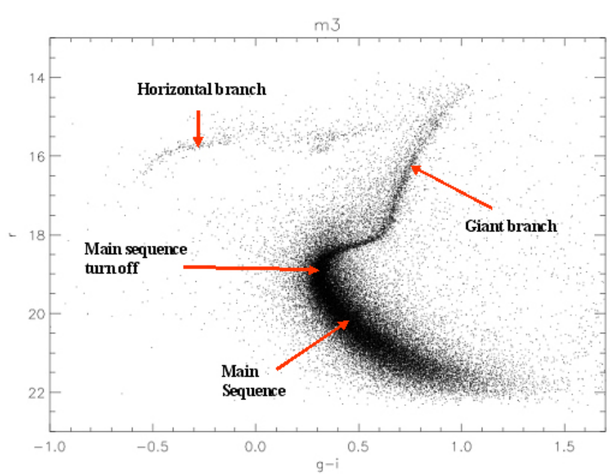

Figure 2: An HR diagram for a single star cluster. The x and y scales are proxies for temperature and luminosity.

i. Unlike the whole-sky HR diagram from Hipparcos, the cluster HR diagram has a clear main-sequence turn-off. Using what you know about star clusters, **explain the origin** of this feature. **How could we use it** to determine the age of a cluster?

ii. In the long run, **what would you expect to happen** to the main-sequence branch of this cluster?