Homework 7

Due **October 22 by 10:45am via Canvas upload**
Please show all work, writing solutions/explanations clearly, or no credit will be given. You are encouraged to work together, but everyone must turn in independent solutions; do not copy from others or from any other sources.

1. For stars without a distance measurement, a distance can be estimated from their spectral type and luminosity class, a method called "spectroscopic parallax." These estimates are more accurate for some types than others; for example, luminosity class III stars on the Horizontal Branch (so named because they are arrayed horizontally on certain color-magnitude diagrams) have absolute magnitudes $M_V = 0.5 \pm 0.2$. Using slide #17 from the Week 8 lectures, estimate the distance (including error bars) to the globular cluster M3.

2. In the Sun's core, the opacity $\kappa \approx 0.12$ m^2 kg^{-1}, and the mass density $\rho \approx 1.5 \times 10^5$ kg m^{-3}. In the stellar photosphere, the opacity drops to 0.03 m^2 kg^{-1}, and the mass density to 1.5×10^{-4} kg m^{-3}.

   (a) What is the mean free path for photons in the Sun's core?

   (b) What is the mean free path for photons in the Sun's photosphere?

   (c) Photons escape the Sun via a "random walk" process, which means that every time a photon interacts with a particle, it gets scattered into a random direction. The result of this process is that, if it were to take the photon N direct steps (or scatterings, but with no change of direction) to reach the surface of the Sun from the center, it will take N^2 steps for the photon to reach the surface via a random walk. Estimate how long it takes for a fusion-created photon to escape the Sun.

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3. At the start of the horizontal branch phase of a 1 $M_\odot$ star's lifetime, about 10% of the original stellar mass is in the form of helium nuclei ($m_{\rm He} = 6.647 \times 10^{-27}$ kg). While on the horizontal branch, the star powers itself via the "triple-α process," in which three helium nuclei are converted in one carbon nucleus ($m_{\rm C} = 1.993 \times 10^{-26}$ kg).

   (a) How much energy is released per triple-α reaction?

   (b) What is the total energy released by fusing this amount of helium into carbon via the triple-α process?

   (c) While on the horizontal branch, the star's luminosity is $L = 100 L_\odot$. If all of this luminosity is provided by the triple-α process in the stellar core, how long will the horizontal branch phase last?

4. Complete Step 1 in the Timeline for your Communicating Science Project. If working in a group, all members should describe their concept and possible approaches and list the other members of the group.