Level 2 Stars, Workshop 8

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Stellar Evolution

a) Draw a Hertzsprung-Russell diagram to illustrate the evolution of a low-mass (~1 solar mass) and high-mass (~25 solar masses) star. Clearly label the axes, mark the track of the main sequence, and draw tracks to indicate the post-main sequence evolution of these stars up to (and including) the red giant-branch phase.

   a. What factors drive the evolution of stars?
   b. What limits the maximum luminosity of a star of a given mass?
   c. What causes the high luminosities of stars on the red giant-branch phase?
   d. When the Sun reaches the red giant-branch phase it will have an effective temperature of 3,000 K and a luminosity 1,000 times higher than that of the Sun. What will be the radius of the Sun, expressed in solar radii?

b) The efficiency of the triple-alpha process is 0.07%. Use this information to calculate the lifetime of the Sun on the horizontal branch assuming that 10% of the mass of the Sun is used for nuclear fusion and that the Sun will be 5 times more luminous than it is now. Give your answer in years. The main sequence lifetime of the Sun is 10^{10} years. Explain why the horizontal-branch lifetime is so much shorter than the main-sequence lifetime.

c) Briefly describe the last day of nuclear fusion in a star of 20 solar masses. Include in your description explanations of the terms 'Silicon burning', 'Photodisintegration', 'Electron capture', 'Core collapse', 'Core rebound', and 'Supernova'.

d) List the four forces preventing the collapse of a normal star, a white dwarf, a neutron star, and a black hole, respectively.

e) Astronomers identify a strange star that is as luminous as the Sun but produces emission that peaks at 0.7 keV. What type of star have they identified? The star is found to have a rotation period of P=0.0003 secs. Calculate the mass of the star, assuming it to be maximally rotating.

f) Provide two pieces of evidence that most pulsars are rotating neutron stars. Why are pulsars rotating so rapidly?

[$L_\odot = 3.84 \times 10^{26}$ W; $T_\odot = 5800$ K; $M_\odot = 1.99 \times 10^{30}$ kg; $R_\odot = 6.96 \times 10^{8}$ m; $m_H = 1.67 \times 10^{-27}$ kg; $k = 1.38 \times 10^{-23}$ J K^{-1}; $c = 3.00 \times 10^{8}$ m s^{-1}; $a = 7.57 \times 10^{-16}$ J m^{-3} K^{-4}; $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}; $G = 6.67 \times 10^{-11}$ N m^{-2} kg^{-2}; $h = 6.63 \times 10^{-34}$ J s; 1 eV = 1.60×10^{-19} J]