Homework # 6 - Supernovae

Due: Thursday, April 20 at 2:00pm
Reading: Lecture Notes, Pols chapter 10, BOB chapter 13.

Instructions: Homework must be highly legible, on white paper, and with multiple pages stapled. List at the top:

- Your name.
- Collaborators (if applicable).
- Estimated time spent to complete.

Homeworks are due at the beginning of class. Late homeworks will be marked down by 50% until the assignment is graded and returned, and will receive no credit after that. Clearly outline the process for solving the problem: partial credit will be given for presenting the correct steps to solve problem, even if you do not achieve the correct numerical answer.

Problems (3 questions, 20 total points):

1. A $10M_\odot$ star starts silicon burning until its degenerate iron core exceeds the Chandrasekhar limit and causes a supernova. (**10 pts total**)

   (a) How much energy is released by the change in gravitational potential energy of the core? (**3 pts**)

   (b) The supernova photodisintegrates the iron ($^{56}_{26}$Fe) into 30 neutrons and 26 protons. How much energy does this take for all of the iron in the star? (**2 pts**)

   (c) The collapsing core has a density of $>10^{11}$ g cm^{-3}, driving electron capture: $p + e^- \rightarrow n + \nu_e$. Assume that the final neutron star has only neutrons (this is not completely true, but we'll ignore quark generation and remaining protons and electrons here). How many neutrinos are generated from electron capture in the core? (**2 pts**)

   (d) What is the typical energy of each neutrino? You can assume that all of the energy remaining after photodisintegration goes into the neutrinos. (This is a good assumption, since only 1% of the energy goes into the expanding shell and only 0.01% goes into radiation). (**3 pts**)

2. Sirius A is a main-sequence A star with a mass of $2.1M_\odot$, and Sirius B is a white dwarf with a mass of $1.0M_\odot$. Sirius A will eventually (in $\sim$1.5 billion years) leave the main sequence and reach a maximum radius of about $400R_\odot$ on the asymptotic giant branch. At what binary separation will the future Sirius A AGB star overflow its Roche lobe and lose mass onto an accretion disk around the Sirius B white dwarf? (**5 pts**)

3. You may have noticed that the masses of Sirius A and Sirius B are unusual, since massive stars evolve more quickly than low-mass stars. The Sirius binary system is $\sim$240 Myr old. What was the minimum initial mass of Sirius B? How much of the mass lost by Sirius B (by stellar winds and a planetary nebula) was captured by Sirius A? (**5 pts**)

Extra Question for 6710 (1 question, 5 total points):

4. One possible explanation for dark matter is a distribution of stellar-remnant black holes. What supernova rate would be required to build the dark matter halo of the Milky Way? Clearly state your assumptions and references used to solve this problem. (**5 pts**)