Solar Physics 2010: Exercises to Lecture 4
Due: 17. May 2010 at 11:00

C.U.Keller

May 9, 2010

1 Stellar diameters in HR diagram

Stars of equal radius are located on curves in the HR diagram. Explain why they are located on curves and determine the type of curves.

2 Solar energy output

Calculate the solar energy output using a solar constant of 1.4 kW/m^2.

3 Solar lifetime

Based on the solar energy output obtained in the previous exercise, determine the lifetime of the Sun if the energy is generated based on

1. the Sun is made of coal and oxygen in the right ratio to burn the coal into CO_2 (hint: assume that burning one kg of coal produces 25 MJ of energy).
2. the Sun is made of hydrogen and oxygen in the optimum ratio (hint: the energy release is about 120 MJ per kilogram of hydrogen).
3. gravitational contraction (hint: use the virial theorem to relate thermal and potential energy).
4. the standard fusion processes (hint: make use of the fact that $\frac{m_{4\mathrm{H}}-m_{\mathrm{He}}}{m_{4\mathrm{H}}} = 0.007$ and think about what conditions are required for fusion to occur.)

4 Number of photons from stars

Show the the number of photons coming from a given area on the sky for a given telescope for a resolved star only depends on the star's surface temperature.

5 Stix problem 2.1: Solar Age

Show how two samples with different Rb/Sr abundance ratios can be used to determine their (common) age.

6 Stix problem 2.2: Minimum Cloud Mass

Transform the Jeans criterion ($\frac{Gm_c}{r} > \frac{RT}{\mu}$) into a condition for the cloud mass, at given interstellar density and temperature. Show that about 10^3 solar masses is the minimum required for instability, at typicaly interstellar conditions: $T = 50$ K and $\rho = 10^{-20}$ kg/m^3. Show that, as the collapse goes on, the conditions become more favorable for further collapse.

7 Stix problem 2.3: Free-Fall Time

Calculate the free-fall time $t_{\rm ff}$, i.e. the time which a spherically symmetric cloud of initial density ρ_0 and negligible internal pressure needs for complete collapse.

8 Stix problem 2.10: Virial Theorem

Suppose the Sun consists of a perfect, monatomic gas in hydrostatic equilibrium. Calculate the internal energy, and compare it to the gravitational energy. Find a lower bound for the mean (mass-weighted) temperature in the Sun. Compare the result with the temperature of the solar model in Table 2.4.

9 Stix problem 2.19: Nuclear Reaction Rates

Write the nuclear reaction rates listed in Table 2.3 in the form $r = r_0 T^\eta$ and calculate r_0 and η at various temperatures between 10^7 K and $1.6 \cdot 10^7$ K. Determine the branching ratios for the pp chains for the solar center using the values in Table 2.4.