Assignment #1: due Tuesday, Oct. 23

Theoretical Astrophysics

Winter 2006/2007
lecturer: Prof. Ralf Klessen, ITA Albert-Ueberle-Str. 2

1. **Number of stars in Milky Way** 5 pt

   Does the Milky Way Galaxy contain more stars than there are grains of sand in the beach volleyball court at the Neckarwiese? Please justify your answer using simple order-of-magnitude estimates.

2. **Timescale estimates for the Sun** 20 pt

   (a) *Dynamical timescale:* The collapse timescale for a self-gravitating object is given by $t_{\rm dyn} \approx 1/\sqrt{G\,\rho}$. Calculate it for the Sun assuming a mean density of $\rho = 1.4\,{\rm g\,cm^{-3}}$

   (b) *Sound crossing time:* The sound speed in the solar core is roughly $350\,{\rm km\,sec^{-1}}$. How long does a sound wave need to cross the Sun assuming a constant sound speed throughout the Sun (the solar radius is $6.96 \times 10^5\,{\rm km}$).

   (c) *Nuclear timescale:* The Sun's energy is produced by the process of fusion of hydrogen into helium. If 10% of the solar mass is consumed in this process during the Sun's lifetime, how long does the Sun's energy production persist if the Sun's energy loss (i.e. luminosity: $L_\odot = 3.846 \times 10^{33}\,{\rm ergs\,sec^{-1}}$) is constant during that time. Use the formula $\tau = E/\dot{E}$ to estimate the nuclear time scale. Note that 0.7% of the hydrogen rest mass is turned into energy in the fusion process.

   (d) *Kelvin-Helmholtz timescale:* The Kelvin-Helmholtz timescale is the ratio of the gravitational energy of an object to its luminosity. Calculate the Kelvin-Helmholtz timescale for the Sun, assume the Sun has a constant density.

3. **Angular momentum** 10 pt

   (a) Estimate the total angular momentum of a 0.1 pc (pc $= 3.085 \times 10^{18}\,{\rm cm}$) size molecular cloud core with a mean density of $\rho = 1.67\times10^{-20}\,{\rm g\,cm^{-3}}$ and a constant angular velocity of $\Omega = 10^{-14}\,{\rm rad\,sec^{-1}}$.

   (b) Assuming the above cloud collapses to a single solar type star, what would be the rotational velocity at its surface (solar mass $M_\odot = 1.989 \times 10^{33}\,{\rm g}$)? Could gravity hold this object together? Discuss this result.

   (c) Calculate the total angular momentum of the Sun assuming a mean rotational period of 30 days.