# Assignment 1

Feb 3, 2015

### Exercise 1: I know it when I see it:

It is difficult to give a definition of a star that covers all possibilities. Discuss this point with your colleagues – over a cappuccino – keeping the following objects in mind: Jupiter, protostar, brown dwarf, white dwarf, neutron star, death star.

### Exercise 2: Sketch the HR diagram. Define the following stellar objects and, if possible, locate them on the HR diagram.

a) Dwarfs
b) Sub-giants
c) Giants
d) Asymptotic Giant Branch stars
e) Horizontal Branch & red clump stars
f) Blue stragglers
g) Carbon stars & S-stars
h) White dwarfs
i) Planetary nebulae
j) Brown dwarfs
k) Cataclysmic variables
l) Symbiotic stars
m) Supernova type Ia
n) Nova
o) Luminous Blue variables
p) Supergiants
q) Hypergiants
r) Wolf-Rayet stars (WN, WC)
s) B[e] stars
t) Supernovae
u) Neutron stars
v) Stellar black holes

### Exercise 3:

The lecture notes show a few examples of Hertzsprung-Russell diagrams. Discuss their similarities and differences.

### Exercise 4: Estimate the stellar central pressure and temperature

Use the equation for hydrostatic equilibrium. Replace the left-hand side by $\Delta P/R$ and then use the average density to derive an expression for the central pressure.

a) Estimate the central pressure for the Sun and compare to the actual value ($P_c \sim 10^{17}$ dyne/cm$^2$).

b) Use the ideal gas law and estimate the central temperature and compare to the actual value ($T_c$~1.4 $10^7$ K).

c) Why is the estimate for the central temperature so much better than for the central pressure ?

## Exercise 5: Improved estimates of the stellar central pressure and density

As discussed in the lecture, estimates for the central conditions depend on the adopted density distribution. Assume a density law given by

$$\rho = \rho_c \left(1 - \left({}^{r}/_{R}\right)^2\right)$$

a) Derive an expression for the mean density
b) Derive an expression for the central pressure
c) Estimate the central temperature using the ideal gas law
d) Calculate the central pressure and temperature for the Sun and for an O5 star (60Msun, 13.4Rsun)
e) Compare these values with those in the attached table and comment on the results

TABLE 2.2. ZAMS models (continued)

| No | $\mathcal{M}/\mathcal{M}_\odot$ | $T_{c,6}$ | $\rho_c$ | $\log P_c$ | $q_c$ | $q_{env}$ |
|---|---|---|---|---|---|---|
| 1 | 60 | 39.28 | 1.93 | 16.22 | 0.73 | 0 |
| 2 | 40 | 37.59 | 2.49 | 16.26 | 0.64 | 0 |
| 3 | 30 | 36.28 | 3.05 | 16.29 | 0.56 | 0 |
| 4 | 20 | 34.27 | 4.21 | 16.37 | 0.46 | 0 |
| 5 | 15 | 32.75 | 5.48 | 16.44 | 0.40 | 0 |
| 6 | 10 | 30.48 | 8.33 | 16.57 | 0.33 | 0 |
| 7 | 7 | 28.41 | 12.6 | 16.71 | 0.27 | 0 |
| 8 | 5 | 26.43 | 19.0 | 16.84 | 0.23 | 0 |
| 9 | 3 | 23.47 | 35.8 | 17.06 | 0.18 | 0 |
| 10 | 2 | 21.09 | 47.0 | 17.21 | 0.13 | neg. |
| 11 | 1.75 | 20.22 | 66.5 | 17.25 | 0.11 | neg. |
| 12 | 1.50 | 19.05 | 76.7 | 17.28 | 0.07 | neg. |
| 13 | 1.30 | 17.66 | 84.1 | 17.28 | 0.03 | neg. |
| 14 | 1.20 | 16.67 | 85.7 | 17.26 | 0.01 | $10^{-7}$ |
| 15 | 1.10 | 15.57 | 84.9 | 17.22 | 0 | $5 \times 10^{-5}$ |
| 16 | 1.00 | 14.42 | 82.2 | 17.17 | 0 | 0.0035 |
| 17 | 0.90 | 13.29 | 78.5 | 17.11 | 0 | 0.020 |
| 18 | 0.75 | 10.74 | 81.5 | – | 0 | – |
| 19 | 0.60 | 9.31 | 79.1 | – | 0 | – |
| 20 | 0.50 | 9.04 | 100 | 17.10 | 0 | – |
| 21 | 0.40 | 8.15 | 104 | 17.04 | 0 | – |
| 22 | 0.30 | 7.59 | 107 | 17.05 | • | 1 |
| 23 | 0.20 | 6.53 | 180 | 17.24 | • | 1 |
| 24 | 0.10 | 4.51 | 545 | 17.68 | • | 1 |
| 25 | 0.08 | 3.30 | 775 | 17.83 | • | 1 |