PHAS1102 – Physics of the Universe
Problem class 2 – Stellar astrophysics (Raman Prinja)
Notes for answers

Problem sheet 1- The marked Problem sheet 1 for PST Group should be returned during this PST session (makers have provided you with a copy of the questions and solutions). There may be some further feedback to provide on individual questions. (Unlikely that you need to go through every question.)

Some **additional problem sets** are added below, covering material on magnitudes, energy generation and stellar evolution. In addition to normal 'problem-style' questions (1 and 2), I've suggested some checks of their conceptual understanding of the basics of stellar evolution – these might provide a refreshing change for the students and you!

Question 1

From $(B-V) = -0.2$ and $(B-V)_o = -0.3$ we get a colour excess
$E(B-V) = (B-V) - (B-V)_o = 0.1$
and then $A_V \sim 3.1\,E(B-V) = 0.3$.

The colour of the star is redder than if there was no extinction because dust scatters blue light more than red.

Applying the distance modulus equation: $m_V - M_V = 5\log_{10} d - 5 + A_V$ we get
$1.0 + 3.4 = 5\log_{10} d - 5 + 0.3$ and $d = 66$ pc

We can apply the expression relating flux ratios and magnitude differences to the absolute visual magnitudes of the star and the Sun:

$$M_{\rm Sun} - M_{\rm star} = 2.5\log_{10}\frac{f_{\rm star}}{f_{\rm Sun}} = 4.8 + 3.4 = 8.2$$

thus

$$\frac{f_{\rm star}}{f_{\rm Sun}} = 1905$$ i.e. the star is approximately 2000 times brighter than the Sun in the V band.

In general $M_{\rm bol} = M_V + BC$

so the bolometric magnitudes of the star and the Sun will be -6.4 and 4.7 respectively.

Using the general expression for the magnitudes difference, this time relating it to the bolometric luminosities ratio, we get:

$M_{\rm bol}(\rm Sun) - M_{\rm bol}(\rm star) = 2.5\log_{10}(L_{\rm star}/L_{\rm Sun}) = 4.7 + 6.4 = 11.1$

and $L_{\rm star} = L_{\rm Sun} \times 10^{11.1/2.5} = L_{\rm Sun} \times 10^{4.44} = 1.1 \times 10^{31}$ W

Question 2

The mass of the star is M = 10 solar masses = 2 x 10^{31} kg
and its luminosity L = 10^4 solar luminosity = 4 x 10^{30} J s^{-1}

The total energy that the star will be able to radiate is

$$E_{total} = 0.0071 \times 0.1 \times M \times c^2$$

$$= 0.0071 \times 0.1 \times (2 \times 10^{31}) \times (9 \times 10^{16}) \text{ Joule}$$

$$= 1.3 \times 10^{45} \text{ Joule}$$

and it will radiate for

$$\frac{E_{total}}{L} = \frac{1.3 \times 10^{45}}{4 \times 10^{30}} \text{ s} = 3 \times 10^{14} \text{ s} = 10^7 \text{ yr}$$

The star is much more massive than the Sun, thus it evolves faster. It is likely that the core of the star will eventually collapse to a neutron star.

Question 3

Hydrostatic equilibrium is a balance between the force of gravity inward and the pressure of hot gases pushing outward. A balance or ‘equilibiurm’ must be attained in order for a star to have a stable size. Main sequence stars have reached such a balance.

Question 4

When a star runs out of hydrogen (as nuclear fuel) in its core, the core collapses. As a result, the Core’s temperature increases and additional energy is radiated away. With a slightly higher temperature, the fusion in the hydrogen shell around the core becomes more efficient. So overall the star puts out more energy than it did as a main sequence star. The increased gas pressure pushes on the outer part of the star, expanding it into a red giant.

(Conceptual) Discussion questions:

- Why are stars not eternal?
- Why is there such a rich diversity of stars in the sky?
- What are the different stellar life paths?
- What key factors do the life paths depend on?
- What are the end-states of evolution?