Astrophysics PST (2) - Solutions

1. The mass of the star is M = 5 solar masses = 1 x 10^{31} kg
and its luminosity L = 600 solar luminosity = 2.28 x 10^{29} J s^{-1}

Fraction of mass liberated per H-butning reaction =
Mass deficit/mass of 4 protons = 0.0286/4.0312 = 0.0071

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

$$E_{total} = 0.0071 \times 0.1 \times M \times c^2$$
$$= 0.0071 \times 0.1 \times (1 \times 10^{31}) \times (9 \times 10^{16}) \text{ Joule}$$
$$= 6.39 \times 10^{44} \text{ Joule}$$

and it will radiate for

$$\frac{E_{total}}{L} = \frac{6.39 \times 10^{44}}{2.28 \times 10^{29}} \text{ s} = 2.8 \times 10^{15} \text{ s} = 8.9 \times 10^{7} \text{ yr}$$

[Btw, check understanding of what is meant by hydrostatic equilibrium!
I.e. a balance between the force of gravity inward and the pressure of hot gases pushing outward.
A balance or 'equilibrium' must be attained in order for a star to have a stable *size*.]

2.

Schwarzchild radius $R_{sch} = 2\ G.M/c^2$

$= (2 \text{ x } 6.67 \text{ x } 10^{-11} \text{ x } 2 \text{ x } 10^{30} \text{ x } 10^{8})/(3 \text{ x } 10^{8})^2$

$= 2.96 \text{ x } 10^{11}$ m = 423 solar radii

Average density = mass/volume = $M/(4/3\ \Pi\ R^3)$

$= (10^{8} \text{ x } 2 \text{ x } 10^{30})$ kg / $(4/3\ \Pi \text{ x } (2.96 \text{ x } 10^{11})^3)$

$= 1.8 \text{ x } 10^{3}$ kg m^{-3}

3.

a) According to Hubble classification scheme:

SBc galaxy -- galaxy has a small nucleus, with a bar-like structure through it. The spiral arms emerge from the ends of the bar and are loosely wound.

Sa galaxy $-$ galaxy has a relatively large nucleus, plus tightly wound spiral arms (no central bar).

To shift Lyα from visible (rest wavelength 121.6 nm) to visible (> 370 nm)

Redshift $z = \Delta\lambda/\lambda = (370.0 - 121.6)/121.6 = 2.04$

For redshifts 2.04 or greater the Lyα line will be shifted to wavelengths longer than 370 nm.

Quasar 3C 273 distance:

Hubble law, distance $d = v / H_o = c\, z / H_o$

$= 3 \times 10^5 \times 0.16 / 75 = 640$ Mpc

4.

$$f_{\text{Andromeda}}/f_{\text{quasar}} = (L_{\text{Andromeda}}/L_{\text{quasar}})(d^2_{\text{quasar}}/d^2_{\text{Andromeda}})$$
$$d^2_{\text{quasar}}/d^2_{\text{Andromeda}} = (f_{\text{Andromeda}}/f_{\text{quasar}})(L_{\text{quasar}}/L_{\text{Andromeda}})$$
$$d_{\text{quasar}}/d_{\text{Andromeda}} = \sqrt{(f_{\text{Andromeda}}/f_{\text{quasar}})(L_{\text{quasar}}/L_{\text{Andromeda}})}$$
$$d_{\text{quasar}}/d_{\text{Andromeda}} = \sqrt{(10^4)(10^3 L_{\text{MW}}/3L_{\text{MW}})}$$
$$d_{\text{quasar}} = \sqrt{10^7/3} \times 0.7 \text{ Mpc} = 1826 \times 0.7 \text{ Mpc} = 1.28 \times 10^3 \text{ Mpc}$$

5.

$$v^2_{\text{rot}} = \frac{GM}{r}$$

$$v^2_{\text{rot}} = \frac{6.7\times10^{-11}\times1.2\times10^{11}\times2\times10^{30}}{8.5\times10^3\times3.1\times10^{16}}$$

$$v_{\text{rot}} = 247 \text{ km s}^{-1}.$$

For circular orbit, $P(\text{orb}) = 2\pi r/v_{\text{rot}}$

$$= \frac{2\pi\times8.5\times10^3\times3.1\times10^{16}}{2.47\times10^5} \times \frac{1}{3.16\times10^7} = 2.1 \times 10^8 \text{ yr}$$

6.

Collapsing gas cloud model:

Galaxy was initially spherical covering the ~ extent of the current halo.
As *Galaxy evolved the gas cloud collapsed into the current disk*.
Thus the *halo stars were formed first* (from the *primordial material*, H, He) while the disk stars are continuing to form. The older halo stars are therefore lower metal abundance (Pop II) since the original gas had low metals. The more recently formed disk stars *follow from previous cycles of stellar evolution and nuclear processing* which adds metal rich material to the disk. Thus younger disk stars are higher metal abundance (Pop I).

7) *Thought of the Day:*

Radio, far-infared and mm observations of objects in the Galaxy reveal its spiral shape. Observations at these wavebands penetrate the obscuring interstellar dust clouds and so the entire disk of the Galaxy can be mapped.