SPA7010U/SPA7010P: THE GALAXY

Coursework 3

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Question 3.1 **[Assessed question]**

(a) Observations of the extinction of starlight by dust show that the ratio of colour excesses, $E_{\mathrm{U-B}}/E_{\mathrm{B-V}}$, for the (U–B) and (B–V) colour indices is nearly constant across the Galaxy, regardless of the strength of the extinction.

Show that the parameter

$$Q \equiv (\mathrm{U-B}) - \frac{E_{\mathrm{U-B}}}{E_{\mathrm{B-V}}}(\mathrm{B-V})$$

is independent of interstellar extinction. (Note that U, B and V are magnitudes in the near ultraviolet, in the blue and in the visual parts of the spectrum.) [16 marks]

(b) A hot main sequence star in the Galactic plane is observed to have magnitudes U = 12.35, B = 12.69 and V = 12.00. What is the Q parameter for this star given that a standard value for $E_{\mathrm{U-B}}/E_{\mathrm{B-V}}$ is 0.72 in the Galaxy? [4 marks]

(c) The table below lists intrinsic colour indices, Q values and absolute magnitudes in the V band for different types of main sequence stars. Using the table, identify the spectral type of the star. [2 marks]

Spectral type	O5V	B0V	B5V	A0V
$(\mathrm{B-V})_0$	−0.35	−0.31	−0.16	0.00
Q	−0.90	−0.84	−0.43	0.00
M_V	−5.8	−4.1	−1.1	+0.7

(d) Estimate the (B-V) colour excess $E_{\mathrm{B-V}}$ of the star. [5 marks]

(e) Using a suitable approximate value for the reddening ratio for interstellar dust, estimate the V-band extinction, A_V, in the V band towards the star. [4 marks]

(f) Estimate the distance of the star from the Sun in kpc. [14 marks]

(g) If the star has a Galactic longitude of $l = 180°$, estimate its distance from the Galactic Centre in kpc. [5 marks]

[Total 50 marks]

End of assessed question

Question 3.2

(a) Describe briefly the physical processes responsible for the ionisation of H II regions and the production of emission lines in their spectra.

(b) What is the origin of the 21cm radio emission from the interstellar medium of the Galaxy? Why is this line impossible to observe directly in the laboratory?

(c) A star has an oxygen-to-iron abundance ratio 1/10th that in the Sun by number. What is the [O/Fe] parameter?

(d) The mean density in the form of stars in the disc of the Galaxy is observed to vary with the distance z from the Galactic plane as $\rho_s(z) = \rho_{so} e^{-|z|/h_s}$ close to the Sun, where ρ_{so} is the density of stars in the plane, and h_s is a scale height. The density of the interstellar gas ρ_g is also found to vary roughly exponentially with height with $\rho_g(z) = \rho_{go} e^{-|z|/h_g}$, where ρ_{go} and h_g are constants. Observations show that $h_s = 250$ pc, $h_g = 150$ pc and $\rho_{so} = 6\,\rho_{go}$.

What is the ratio of the surface density of stars, Σ_s, to that of gas, Σ_g, at the Sun's distance from the Galactic Centre?

(e) How would you expect the surface density of the dust, Σ_d, to compare with Σ_s?

Question 3.3

(a) Briefly state which processes produced, respectively, (i) most of the helium and (ii) most of the heavy elements in the Galaxy.

(b) How does the metallicity Z behave formally as the gas fraction $\mu \to 0$ in the Simple Model of chemical evolution?

State whether this physically realistic, briefly justifying your answer.

(c) Show that in the Simple Model, the mean metallicity of a population of long-lived stars is given by

$$\langle Z \rangle \;=\; p \left(\frac{M_{\rm gas}(0)}{M_{\rm stars}} - 1 \right) \ln \left(1 - \frac{M_{\rm stars}}{M_{\rm gas}(0)} \right) \;+\; p \;,$$

where $M_{\rm gas}(t)$ is the mass of gas in the volume at time t, $M_{\rm stars}(t)$ is the mass of stars at time t, and p is the yield (the proportion of new metals synthesised by the star).

[Continued ...]

(d) Show that the expression in (c) can be written as $\langle Z \rangle = p\left(1 + \frac{\mu \ln \mu}{1-\mu}\right)$ in terms of the gas fraction μ.

(e) What is the mean metallicity $\langle Z \rangle$ when the gas fraction $\mu \to 0$ as gas is used up entirely in star formation?

You may find helpful the standard integral

$$\int \ln(1 - x/a)\,\mathrm{d}x = (x-a)\ln(1-x/a) - x + \text{constant}.$$

[Hint: the mean metallicity can be represented as $\langle Z \rangle = \frac{\int_0^{M_\mathrm{stars}} Z\,\mathrm{d}M'_\mathrm{stars}}{\int_0^{M_\mathrm{stars}} \mathrm{d}M'_\mathrm{stars}}$.]