2021 Ph H2 Q6

Section: Particles and Waves / Our Dynamic Universe

Topic: Spectra & Redshift

Fraunhofer absorption lines in solar spectrum. (a)(i) Calculate frequency for transition E1 → E4. (a)(ii) Calculate wavelength. (a)(iii) Identify colour. (b) Galaxy NGC 6745 recessional velocity 4.51×10^{6} m/s: calculate redshift. (c) Explain how redshift supports Big Bang theory.

Worked solution

(a)(i) Frequency of absorbed photon

$\Delta E = E_4 - E_1$
$= (-0.81\times10^{-19}) - (-21.8\times10^{-19}) = 2.10\text{e-}18$ J
$f = \Delta E / h = 2.10\text{e-}18 / 6.63\times10^{-34} = 3.17\text{e+}15$ Hz

Answer: 3.17×10^{15} Hz

(a)(ii) Wavelength

$\lambda = c/f = 3.0\times10^{8} / 3.17\text{e+}15 = 9.48\text{e-}08$ m

Answer: 9.5×10^{-8} m = 95 nm

(a)(iii) Colour

λ = 95 nm lies in the ultraviolet region (not visible to human eye).

(b) Redshift

$z = v/c = (4.51\times10^{6})/(3.0\times10^{8}) = 0.015$

Answer: 0.015

(c) If most galaxies show redshift, they are moving away from us. This implies the Universe is expanding. Extrapolating backwards, all galaxies were closer together in the past, consistent with the Big Bang model of an origin in a hot dense state.

Final answers

(a)(i) $f \approx 3.17\times10^{15}$ Hz

(a)(ii) $\lambda \approx 95$ nm (ultraviolet)

(a)(iii) Ultraviolet

(b) $z \approx 0.015$

(c) Redshift → expansion → supports Big Bang

Revision tips

- Photon energy: $E = hf = hc/\lambda$.
- Hydrogen energy levels are negative; $\Delta E = E_{high} - E_{low}$.
- UV wavelengths <400 nm, visible 400–700 nm.
- Redshift $z = v/c$ for low velocities.

- Expansion evidence: galaxies receding, supporting Big Bang.