SPA7010 Example Problems 6
(12 March 2020)

Interstellar Medium and Chemical Evolution

Problem 6.1

(a) Explain the meaning of the terms HI, HII and H_2 referring to hydrogen in the Galaxy, and describe the typical environments in which they are located.

(b) A star lying near the Galactic plane is observed to have an apparent visual magnitude of $V = 11.79$ and an apparent blue magnitude of $B = 12.49$. Comparison of the star's spectrum with standard spectra indicates that it has absolute magnitudes $M_B = 3.20$, $M_V = 2.70$ in these bands. Assuming that the reddening ratio for interstellar dust is $A_V/E(B-V) = 3.0$, estimate (i) the reddening of the star, (ii) the V-band extinction in magnitudes, and (iii) the distance to the star in parsec.

(c) In which region of the electromagnetic spectrum is the CO molecule most easily observed? What type of energy level transitions are responsible for this emission? Why are observations of CO emission used to trace the distribution of cold molecular gas in the Galaxy, rather than observations of H_2 molecules directly

(d) Give the standard definitions of the symbols X, Y, Z, used in the study of Galactic chemical evolution. Quote typical values for these in the local interstellar medium. State which processes respectively produced (i) most of the helium, and (ii) most of the heavy elements.

(e) Under the Simple Model of galactic chemical evolution, the change δZ in the metallicity Z of interstellar gas in a closed volume of space in a short interval of time is related to the change δM_{metals} in the mass M_{metals} of heavy elements in the gas by

$$\delta Z \quad = \quad \frac{\delta M_{\rm metals}}{M_{\rm gas}} \quad - \quad Z\,\frac{\delta M_{\rm gas}}{M_{\rm gas}}$$

where M_{gas} is the mass of gas in the volume. The change in the mass of heavy elements is related to the change δM_{stars} in the mass M_{stars} of stars in the volume by

$$\frac{\delta M_{\rm metals}}{M_{\rm gas}} \quad = \quad -\,Z\,\frac{\delta M_{\rm stars}}{M_{\rm gas}} \quad + \quad p\,\frac{\delta M_{\rm stars}}{M_{\rm gas}}\,,$$

where p is the yield of heavy elements.

Derive from these expressions the relation $Z = -\,p\,\ln\mu$, where $\mu \equiv M_{gas}(t)/M_{total}$ is the fraction of the total mass in the volume in the form of gas.