SPA 7010 Problems 6 (12 March 2020)

6.1 (a) HI - atomic hydrogen, typically found in cool, low density clouds in ISM (~ 100K)

HII - ionised hydrogen, mostly found in 'HII regions' surrounding clusters of hot, young, OB stars ($\sim 10^4$K)

H_2 - molecular hydrogen, mostly found in cold, dense molecular clouds (a few 10's of K).

(b)

Apparent (observed) $B-V = 12.49 - 11.79 = 0.70$ mag

and intrinsic $M_B - M_V = 3.20 - 2.70 = 0.50$ mag

(i) $\therefore$ reddening, $E(B-V) = (B-V) - (M_B - M_V)$

$= 0.70 - 0.50 = \underline{0.20 \text{ mag}}$

(ii) Given reddening ratio is $\frac{A_V}{E(B-V)} = 3.0$

then the V band extinction, A_V is

$A_V = 3.0 \times E(B-V) = 3.0 \times 0.20 = \underline{0.60 \text{ mag}}$

(iii) To find the distance, we can use:

$$m_V - M_V = 5 \log_{10}\left(\frac{d}{\text{pc}}\right) - 5 + A_V$$

$$\therefore 5 \log_{10} d = 11.79 - 2.70 + 5 - 0.60$$

$$= 13.49$$

ie. $\log_{10} d = 2.698$ and $\underline{d \sim 499 \text{ pc}}$

(c) CO is most easily observed at mm wavelengths (radio), emitting at 1.3 and 2.6 mm.
The emission is produced by rotational transitions of molecules.
H_2 produces minimal emission and no radio lines, whereas CO does emit at mm wavelengths, so its distribution can be mapped directly and used to infer the distribution of cold molecular hydrogen in the ISM.

(d)

X - fraction by mass of hydrogen

Y - fraction by mass of helium

Z - fraction by mass of heavy elements ('metals')

Typical values in the local ISM are

$X \approx 0.70$, $Y \approx 0.28$, $Z \approx 0.02$

(i) most of helium is from primordial ('Big Bang') nucleosynthesis.

(ii) most of heavy elements (metals) are produced in stars.