Examining production of HII Regions for different Spectral Types

HII regions are formed by photoionization of the medium surrounding the star. The ionization rate is given by,

$$N_{Ly} = \int_{h\nu=13.6eV}^{\infty} \frac{L_\nu}{h\nu} \tag{1}$$

We know that for an isotropic emission,

$$F_\nu = 4\pi I_\nu$$

Since a star emits isotropically, its luminosity in terms of radius R_s and specific intensity is given by,

$$L_\nu = 16\pi^2 R_s^2 I_\nu$$

A star can be modelled as a black body to a good appoximation. On using the Plank function as specific intensity, we get the luminosity as,

$$L_\nu = \frac{32\pi^2 R_s^2 h\nu^3}{c^2} \frac{1}{e^{\frac{h\nu}{kT}}-1}$$

On putting the above value of L_ν in eq.1,

$$N_{Ly} = \frac{32\pi^2 R_s^2}{c^2} \int_{h\nu=13.6eV}^{\infty} \frac{\nu^2}{e^{\frac{h\nu}{kT}}-1}$$

Let $x = h\nu/kT$. Writing above equation in terms of x,

$$N_{Ly} = \frac{32\pi^2 R_s^2}{c^2} \left(\frac{kT}{h}\right)^3 \int_{13.6eV/kT}^{\infty} \frac{x^2}{e^x-1}$$

$$= \frac{32\pi^2 R_s^2}{c^2} \left(\frac{kT}{h}\right)^3 [\int_0^{\infty} \frac{x^2}{e^x-1} - \int_0^{13.6eV/kT} \frac{x^2}{e^x-1}]$$

$$= \frac{32\pi^2 R_s^2}{c^2} \left(\frac{kT}{h}\right)^3 [\Gamma(3)\zeta(3) - \int_0^{13.6eV/kT} \frac{x^2}{e^x-1}]$$

$$= \frac{32\pi^2 R_s^2}{c^2} \left(\frac{kT}{h}\right)^3 [2 \times 1.202 - \int_0^{13.6eV/kT} \frac{x^2}{e^x-1}]$$

$$\Rightarrow N_{Ly} = \frac{32\pi^2 R_s^2}{c^2} \left(\frac{kT}{h}\right)^3 [2.404 - \int_0^{13.6eV/kT} \frac{x^2}{e^x-1}] \tag{2}$$

In order to examine capability of a certain type of star to form HII region around it, we will have to calculate N_{Ly} for a typical star of their type.

For type O:-
Taking T=36000K and R_s=8.27R_o, eq.2 gives,

$$N_{Ly} = \frac{32\pi^2 R_s^2}{c^2}\left(\frac{kT}{h}\right)^3[2.404 - 2.027]$$

$$\Rightarrow N_{Ly} \approx 10^{49} s^{-1}$$

This value is greater than typical values of recombination rate and therefore, a type O star is capable of producing HII region.

For type B:-
Taking T=25000K and R_s=10R_o, eq.2 gives,

$$N_{Ly} = \frac{32\pi^2 R_s^2}{c^2}\left(\frac{kT}{h}\right)^3[2.404 - 2.305]$$

$$\Rightarrow N_{Ly} \approx 10^{48} s^{-1}$$

This value is greater than typical values of recombination rate and therefore, a type B star is also capable of producing HII region.

For type A:-
Taking T=7112K and R_s=1.55R_o, eq.2 gives,

$$N_{Ly} \approx \frac{32\pi^2 R_s^2}{c^2}\left(\frac{kT}{h}\right)^3[2.404 - 2.404]$$

$$\Rightarrow N_{Ly} \approx 0 s^{-1}$$

Therefore, a type A star is not capable of producing HII region.

Similarly, on calculating for other type of stars we would find that the value of N_{Ly} will be negative and therefore they cannot produce HII regions.
Thus, only type O and type B stars are capable of producing HII regions.