HII regions

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Abstract HII regions are clouds of gas which are kept ionised by a source of ionising radiation. The gas is ionised to a depth known as the Stromgren radius. Emission lines are produced by recombination of ions and electrons in the gas. We review the relevant properties.

1. Recombination rates

Ions and electrons in a plasma at temperature T recombine at a rate $\alpha n_e\ n_i$ per unit volume per unit time, where n_i is the ion density and n_e the electron density in the plasma. The coefficient α is the recombination rate coefficient. Since direct recombinations to the ground state produce an ionising photon (hence a further ionisation) these are usually ignored in α. For hydrogen the coefficient is then, to a sufficient approximation

$$\alpha = \alpha_B = 2.4 \times 10^{-11} T^{-1/2}\ \mathrm{cm}^{-3}\ \mathrm{s}^{-1},$$

$$\alpha_{H\beta} = 3 \times 10^{-14}\ \mathrm{cm}^{-3}\ \mathrm{s}^{-1}.$$

2. Strömgren radius

An ionising source embedded in a uniform spherical nebula ionises material to a radius R_s, the Strömgren radius, given by balancing the rate of input of ionising photons with the rate of recombination. Thus

$$\tfrac{4}{3}\pi R_s^{\ 3} \alpha_B n_e n_i = \frac{L_{\nu > \nu_i}}{h\nu_i}$$

where ν_i is the minimum ionising frequency of radiation and L is the source luminosity above that frequency.

3. Ionisation parameter

The ratio of the number of ions N_u in a plasma in the $(n + 1)^{\mathrm{th}}$ ionised state to those, N_l, in the n^{th} ionised state is governed by the ionisation parameter U, where

$$\frac{N_u}{N_l} = \frac{\sigma_0 c}{\alpha_B} U\ .$$

and $\sigma_0 = 6.3 \times 10^{-18}\ \mathrm{cm}^2$ is the total ionisation cross-section at the ionisation theshhold. At a distance R from a source of Q ionising photons per unit time in a medium of density n,

$$U = \frac{Q}{4\pi R^2 cn}\ .$$