Numerical Models for the Diffuse Ionized Gas in Galaxies. II. Three-dimensional radiative transfer in inhomogeneous interstellar structures as a tool for analyzing the diffuse ionized gas

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Aims: We systematically explore a plausible subset of the parameter space involving effective temperatures and metallicities of the ionizing stellar sources, the effects of the hardening of their radiation by surrounding leaky HII regions with different escape fractions, as well as different scenarios for the clumpiness of the DIG, and compute the resulting line strength ratios for a number of diagnostic optical emission lines.
Methods: For the ionizing fluxes we compute a grid of stellar spectral energy distributions (SEDs) from detailed, fully non-LTE model atmospheres that include the effects of stellar winds and line blocking and blanketing. To calculate the ionization and temperature structure in the HII regions and the diffuse ionized gas we use spherically symmetric photoionization models as well as state-of-the-art three-dimensional (3D) non-LTE radiative transfer simulations, considering hydrogen, helium, and the most abundant metals.
Results: We provide quantitative predictions of how the line ratios from HII regions and the DIG vary as a function of metallicity, stellar effective temperature, and escape fraction from the HII region. The range of predicted line ratios reinforces the hypothesis that the DIG is ionized by (filtered) radiation from hot stars; however, comparison of observed and predicted line ratios indicates that the DIG is typically ionized with a softer SED than predicted by the chosen stellar population synthesis model. Even small changes in simulation parameters like the clumping factor can lead to considerable variation in the ionized volume. Both for a more homogeneous gas and a very inhomogeneous gas containing both dense clumps and channels with low gas density, the ionized region in the dilute gas above the galactic plane can cease to be radiation-bounded, allowing the ionizing radiation to leak into the intergalactic medium.

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