Emission-line diagnostics of HII regions using conditional Invertible Neural Networks

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Young massive stars play an important role in the evolution of the interstellar medium (ISM) and the self-regulation of star formation in giant molecular clouds (GMCs) by injecting energy, momentum, and radiation (stellar feedback) into surrounding environments, disrupting the parental clouds, and regulating further star formation. Information of the stellar feedback inheres in the emission we observe, however inferring the physical properties from photometric and spectroscopic measurements is difficult, because stellar feedback is a highly complex and non-linear process, so that the observational data are highly degenerate.

On this account, we introduce a novel method that couples a conditional invertible neural network (cINN[1]) with the WARPFIELD-emission predictor (WARPFIELD-EMP[2]) to estimate the physical properties of star-forming regions from spectral observations. We present a cINN that predicts the posterior distribution of seven physical parameters (cloud mass, star formation efficiency, cloud density, cloud age which means age of the first generation stars, age of the youngest cluster, the number of clusters, and the evolutionary phase of the cloud) from the luminosity of 12 optical emission lines, and test our network with synthetic models that are not used during training. Our network is a powerful and time-efficient tool that can accurately predict each parameter, although degeneracy sometimes remains in the posterior estimates of the number of clusters. We validate the posteriors estimated by the network and confirm that they are consistent with the input observations. We also evaluate the influence of observational uncertainties on the network performance.

Our network is applicable to the forthcoming SDSS-V LVM survey of ionized gas in the Milky Way and other Local Group galaxies because the choice of emission lines is motivated by the fact that they will be targeted in the LVM survey as well as the strength of the lines. We also apply our method to PHANGS-MUSE survey of HII regions in nearby spiral galaxies, where most of the emission lines are observable by MUSE integral field unit.

References

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