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A neural network approach to 3D NLTE radiative transfer

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Computing synthetic spectra from model atmospheres is a fundamental tool to understand the formation of complex spectra and help guide observations. Forward modelling using 3D MHD simulations is becoming widespread, and with it the need to efficiently carry out radiative transfer computations. This is particularly acute for the solar chromosphere, where out of equilibrium conditions dictate the need for non-LTE calculations, which in 3D are computationally extremely expensive and require a supercomputer. We have developed a neural network approach to greatly speed up 3D non-LTE spectral synthesis. We used a convolutional neural network to learn the full 3D mapping between LTE and non-LTE populations for a given model atom. Once we have the non-LTE populations, synthetic spectra can be quickly computed for any viewing angle and spectral line, assuming complete redistribution (CRD). The "true" values of the non-LTE populations are taken from runs with the Multi3D code. The proposed network architecture successfully learns the population mappings using a combination of simulations with different conditions and magnetic topology. Testing with different snapshots of the simulations used in the training gives a very good agreement, although the network can struggle when using more extreme, out of sample simulations. The results are very encouraging and result on a time saving of about 5 orders of magnitude; running typical-sized problems for a model hydrogen atom takes less than three hours on a consumer GPU.

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