A Deep Learning Neural Network for Voigt Profile Fitting Quasar Absorption Lines

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Abstract

The Voigt Profile (VP) fitting of absorption lines in quasar spectra has been instrumental in our study of cosmic gaseous structures for more than 50 years. VP fitting Lyman-alpha forest lines has been key for constraining the column density distributions, temperatures, and kinematics of the intergalactic medium (IGM). In Lyman-alpha absorption-selected systems, many gas structures in the circumgalactic media (CGM) of galaxies give rise to metal lines spanning a wide range of ionization stages. VP fitting these absorption line systems yields column density constraints for chemical-ionization models from which densities, cloud structures, metallicities, and temperatures can be measured.
VP fitting complex kinematic systems is extremely time consuming; it took more than 3 years for Evans (2011) to fit _˜420 MgII absorption-selected systems from _˜250 HIRES and UVES quasar spectra. If these human-intensive methods aren't replaced by more efficient methods, the field of quasar absorption line spectroscopy will struggle to progress alongside the rest of astronomical research as a whole. In recent years, machine learning (a subfield of artificial intelligence) has been successfully employed in many facets of extragalactic astronomy to analyze data from large surveys. In one instance, a convolutional neural network (CNN) was designed that predicts the redshift and column density of damped Lyman-alpha absorbers (DLAs) in un-normalized SDSS spectra with a reliability matching previous human-generated catalogs. This work eradicated the human-intensive labor of continuum fitting, absorption line searching and identification, and VP fitting.

We are replacing the inefficient human analysis involved in VP fitting metal absorption lines with CNNs that take input absorption spectra and return column densities, Doppler b parameters, and cloud velocities in a matter of seconds. Specifically, we have trained a CNN on one million simulated single cloud MgII doublets with varied signal-to-noise ratios and tested its predictions against a VP fitter using both 100,000 simulated MgII doublets and 56 observed MgII doublets from the sample of Churchill et al. (2020). We find that while our current CNN couldn't match the accuracy of the fitter, it provided an initial model to the fitter that resulted in that fitter giving results statistically consistent with those obtained when a human provided the initial model. Thus, the CNN is able to accurately emulate a human expert's work, giving rise to more than an order of magnitude in time savings.

Poster: in PDF

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Video: https://youtu.be/ZKrH7mlBsVs

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