Spectropolarimetric inversions including physical constraints

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Depth-stratified spectropolarimetric inversions are one of the most insightful approaches to the characterization of the solar atmosphere. These have been performed, almost exclusively, under the assumption of hydrostatic equilibrium in a pixel by pixel basis. This is required as spectral line sensitivity to any other thermodynamic property than temperature is low. Thus, the ability to infer the 3D thermodynamic and magnetic topology of the solar atmosphere is strongly limited. This scientific goal is further hindered by the fact that spectral line is sensitive to the stratification of physical parameters in optical depth rather than geometrical scale, required to address the 3D topology. In recent years, there have been some attempts to overcome these limitations, for instance neural network mappings, radiative magnetohydrodynamic (MHD) assisted inversions, inversions under the assumption of the magnetohydrostatic approximation.
Here we present an alternative approach: use a Physics-Informed Neural Networks to represent the atmosphere in an N-dimensional space (three spatial coordinates and time). This is a different approach to classical deep learning techniques as the neural network provides the atmosphere at the required space-time grid, which feeds a radiative transfer solver (FIRTEZ-dz). The output spectra is then compared to the observations driving the minimization of a likelihood function. In the process, the the atmosphere representation is modified in order to best explain the observations. We explore the benefits (mainly related to the inclusion of soft penalty of un-physical solutions, in the sense of deviations from MHD predictions) and drawbacks of this approach over a synthetic observation. We will specifically consider the case of the magnetic field vector, divergence free solutions, and accuracy on the estimation of electric currents and the three components of the Lorentz force.