University of Chicago Computational and Applied Math Student Seminar Autumn 2022

Learning Coronal Nonlinear Force-Free Magnetic Fields through Differentiable Rendering

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Monday, October 31, 12 – 1 PM, Jones 303

October 26, 2022

Abstract

We consider the ill-posed problem of computing the 3D magnetic field above the surface of the sun (the corona) from the vector magnetic field on the surface (the photosphere) and 2D optical projections of plasma flowing through magnetic field lines. We approximate the coronal magnetic field using the commonly used nonlinear force free field (NLFFF) model. The ill-posedness of this problem has posed challenges for traditional iterative numerical PDE methods, leading us to take a deep learning approach. Using a parameterized NLFFF approximation by Aschwanden (2012), we build a differentiable renderer that is able to synthesize vector magnetograms and images of field lines. Since we wish to be able to reconstruct the coronal magnetic field from real solar data (for which there is no ground truth), we take an unsupervised learning approach by using our differentiable renderer in an autoencoder designed to learn the underlying NLFFF parameters. In particular, our loss function operates only on the rendered magnetograms and field line images; at no point does our training routine access the ground truth NLFFF parameters. We believe that the coupling of a simple physical model with differentiable rendering provides a valuable and novel way of solving ill-posed inverse problems. We will show prediction results of our autoencoder on simulated data.