SWIFT: A Novel Machine-Learning Platform for Space Weather Forecasting from HMI Vector Magnetograms

Kadadi, Yash (School: The Westminster Schools)

Major solar flares (X&M-class) and their resulting Coronal Mass Ejections (CME) and Solar Proton Events (SPE) severely threaten modern human society. A major solar event hitting Earth would disrupt radio communications and decimate our electrical grid, creating massive outages. Consequently, reliable methods of forecasting major flares are needed to preempt solar events and their destructive capabilities. Unfortunately, current models only “nowcast” a few hours in advance or use obsolete datasets. To alleviate these limitations, “SWIFT” (Space Weather Imaging + Forecasting Tool), a next-generation statistical machine-learning model, was built. SWIFT analyzes historical Helioseismic Imager (HMI) magnetogram data to make 24-hour flare forecasts. SWIFT uses mathematical estimates of free-energy trapped in a region (“free-energy proxies”) to predict a region’s flare-rate. By applying image-processing algorithms and analyzing the “neutral-line” between the strong positive and negative magnetic fields, SWIFT calculates an active region’s free-energy proxies. SWIFT analyzed 500,000+ active region patches from 2010-2019, matching them with their major flare event-rates to create its training dataset. SWIFT then references this dataset when analyzing new magnetograms and makes 24-hour forecasts. While multiple free-energy proxies were studied, Gradient matched best with event-rate and was used in the final statistical model. In model validation, SWIFT made predictions with 83.85% accuracy, forecasted 93.11% of major flares 24 hours in advance, and had a peak True Skill Statistic of 0.765. By acting as an early warning system for solar flares, SWIFT’s next-generation machine-learning platform gives much-needed preparation time for avoiding a major flare’s disastrous consequences.