Modelling Space Weather: A New Deep Learning-Based Approach

Radhakrishnan, Aditya (School: Suguna PIP School)

Space weather phenomena, especially magnetic storms that originate in the Sun such as flares and Coronal Mass Ejections (CMEs), have the potential to cripple satellite operations and space-reliant technologies such as telecommunications, navigational networks, and electric power grids on Earth. Space weather impacts of the severest solar storms are estimated to cost trillions of dollars in damages. To drastically mitigate the damages caused by these events, an effective early-warning system is necessary. However, modelling space weather is challenging and the processes that lead to space weather events are not entirely understood. Here, a new space weather forecasting tool based on deep learning is devised, enabling a machine to learn for itself how to predict space weather phenomena. A Convolutional Neural Network was trained to predict 24-hour peak solar X-ray brightness and proton flux readings from magnetic field measurements of the Sun. This is achieved by analysis of magnetograms - images representing variations in magnetic field strength on the Sun‘s surface. Rapid restructuring and evolution of this magnetic field distribution drives solar storms and X-ray flux. There is thus a physical basis motivating our deep learning approach. To enable extended forecasts beyond 24 hours, a second neural network using ConvLSTMs has been trained to predict future magnetograms from a sequence of past magnetograms and dopplergrams (representations of solar surface movements). These predictions can be fed back into the network recursively or be used by the first network to predict solar flares and CMEs. Eight years of GOES-15 and SDO data was collected for training and testing. Test results prove to be promising with prediction accuracies upwards of 80%.