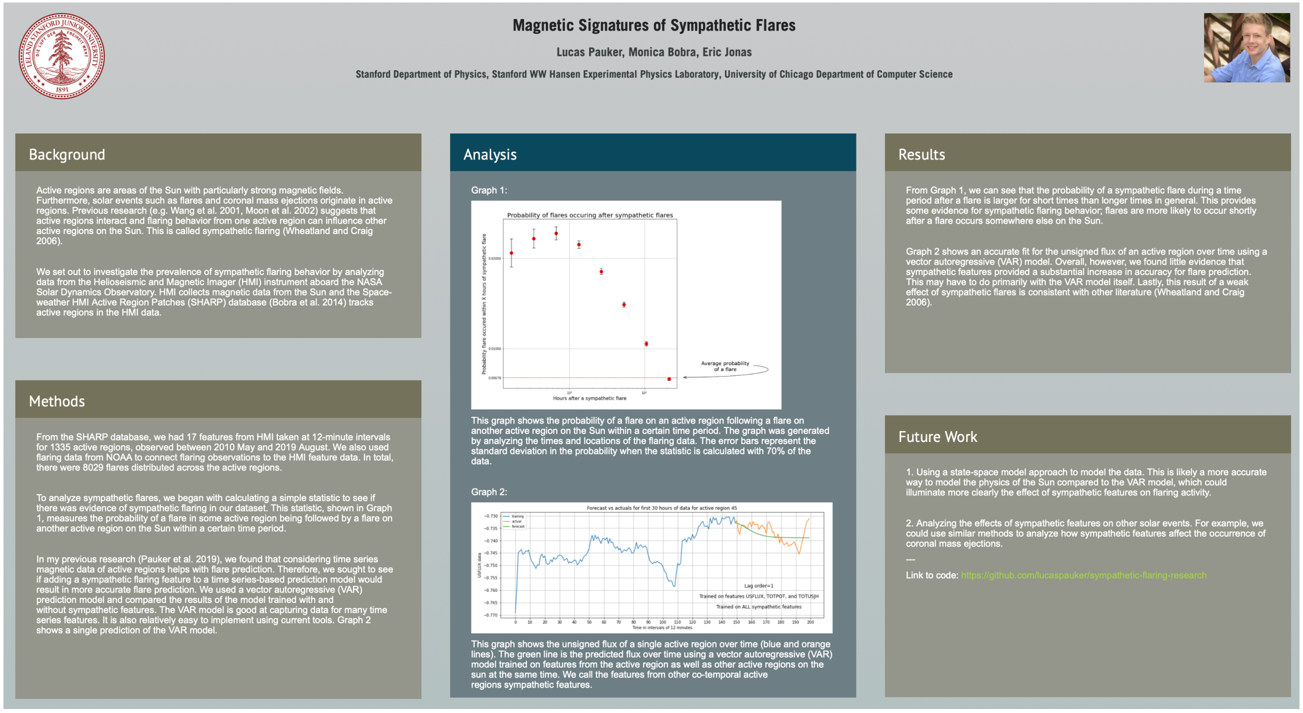
Magnetic Signatures of Sympathetic Flares



Lucas Pauker, Monica Bobra, Eric Jonas

Stanford Department of Physics, Stanford WW Hansen Experimental Physics Laboratory, University of Chicago Department of Computer Science

PRESENTED AT:

BACKGROUND

Active regions are areas of the Sun with particularly strong magnetic fields. Furthermore, solar events such as flares and coronal mass ejections originate in active regions. Previous research (e.g. Wang et al. 2001, Moon et al. 2002) suggests that active regions interact and flaring behavior from one active region can influence other active regions on the Sun. This is called sympathetic flaring (Wheatland and Craig 2006).

We set out to investigate the prevalence of sympathetic flaring behavior by analyzing data from the Helioseismic and Magnetic Imager (HMI) instrument aboard the NASA Solar Dynamics Observatory. HMI collects magnetic data from the Sun and the Space-weather HMI Active Region Patches (SHARP) database (Bobra et al. 2014) tracks active regions in the HMI data.

Currently there is little literature on how photospheric magnetic fields on the Sun relate to sympathetic flaring.

METHODS

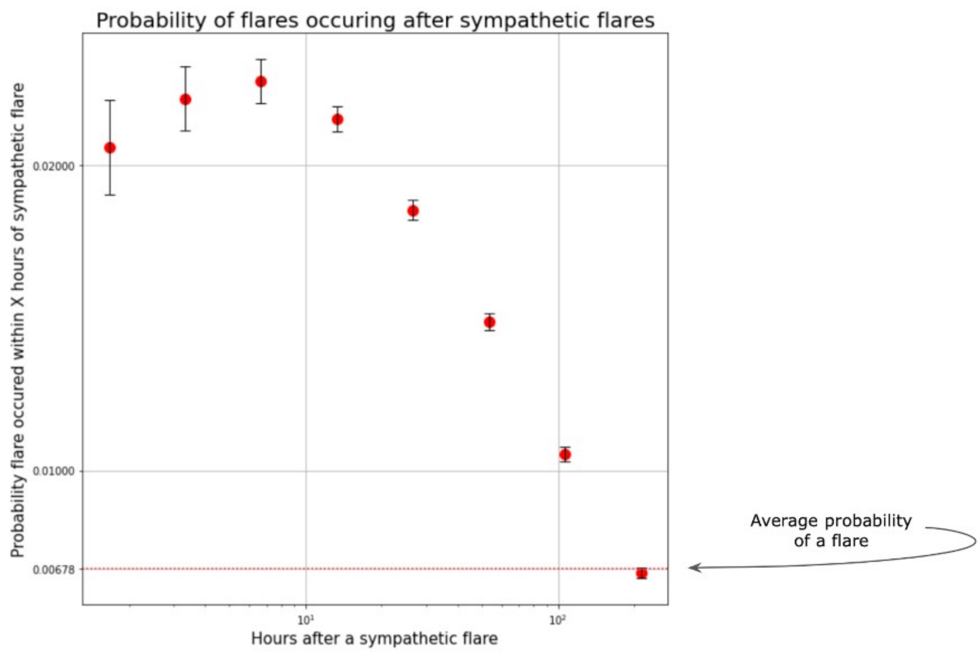
From the SHARP database, we had 17 features from HMI taken at 12-minute intervals for 1335 active regions, observed between 2010 May and 2019 August. We also used flaring data from NOAA to connect flaring observations to the HMI feature data. In total, there were 8029 flares distributed across the active regions.

To analyze sympathetic flares, we began with calculating a simple statistic to see if there was evidence of sympathetic flaring in our dataset. This statistic, shown in Graph 1, measures the probability of a flare in some active region being followed by a flare on another active region on the Sun within a certain time period.

In my previous research (Pauker et al. 2019), we found that considering time series magnetic data of active regions helps with flare prediction. Therefore, we sought to see if adding a sympathetic flaring feature to a time series-based prediction model would result in more accurate flare prediction. We used a vector autoregressive (VAR) prediction model and compared the results of the model trained with and without sympathetic features. The VAR model is good at capturing data for many time series features. It is also relatively easy to implement using current tools. Graph 2 shows a single prediction of the VAR model.

ANALYSIS

Graph 1:



This graph shows the probability of a flare on an active region following a flare on another active region on the Sun within a certain time period. The graph was generated by analyzing the times and locations of the flaring data. The error bars represent the standard deviation in the probability when the statistic is calculated with 70% of the data.

Graph 2:

This graph shows the unsigned flux of a single active region over time (blue and orange lines). The green line is the predicted flux over time using a vector autoregressive (VAR) model trained on features from the active region as well as other active regions on the sun at the same time. We call the features from other co-temporal active regions sympathetic features.

RESULTS

From Graph 1, we can see that the probability of a sympathetic flare during a time period after a flare is larger for short times than longer times in general. This provides some evidence for sympathetic flaring behavior; flares are more likely to occur shortly after a flare occurs somewhere else on the Sun.

Graph 2 shows an accurate fit for the unsigned flux of an active region over time using a vector autoregressive (VAR) model. Overall, however, we found little evidence that sympathetic features provided a substantial increase in accuracy for flare prediction. This may have to do primarily with the VAR model itself. Lastly, this result of a weak effect of sympathetic flares is consistent with other literature (Wheatland and Craig 2006).

FUTURE WORK

1. Using a state-space model approach to model the data. This is likely a more accurate way to model the physics of the Sun compared to the VAR model, which could illuminate more clearly the effect of sympathetic features on flaring activity.
2. Analyzing the effects of sympathetic features on other solar events. For example, we could use similar methods to analyze how sympathetic features affect the occurrence of coronal mass ejections.

Link to code: https://github.com/lucaspauker/sympathetic-flaring-research (https://github.com/lucaspauker/sympathetic-flaring-research)

ABSTRACT

Several studies show that the interaction between active regions can trigger flaring behavior (e.g. Wang et al. 2001, Moon et al. 2002, Schrijver & Title 2011, Shen et al. 2012, and Schrijver & Higgins 2015). This concept, described by Wheatland and Craig (2006) as sympathetic flaring, likely occurs when a flare triggers a global reconfiguration of the solar magnetic field. We attempt to investigate the magnetic signatures of sympathetic flaring by analyzing photospheric magnetic field maps, taken by the Helioseismic and Magnetic Imager (HMI) instrument aboard the NASA Solar Dynamics Observatory, of all the flaring active regions observed between 2010 and 2020. First, we calculate features that describe the aggregate flaring activity on the Sun at any given time. Second, we use vector autoregressive models from the open source scientific software package statsmodels (Seabold and Perktold, 2010) to model the time evolution of these aggregate features along with other physical features of the photospheric magnetic field, such the magnetic energy and flux. We find that sympathetic flaring does exist, but plays a fairly weak role in overall flaring activity. We propose a few other ideas to further investigate sympathetic flaring.