Identification and tracking of small-scale magnetic features on the solar photosphere

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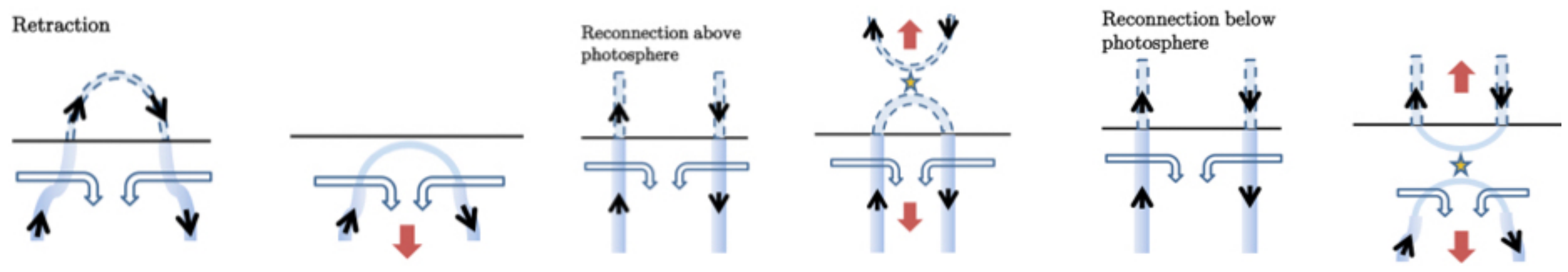
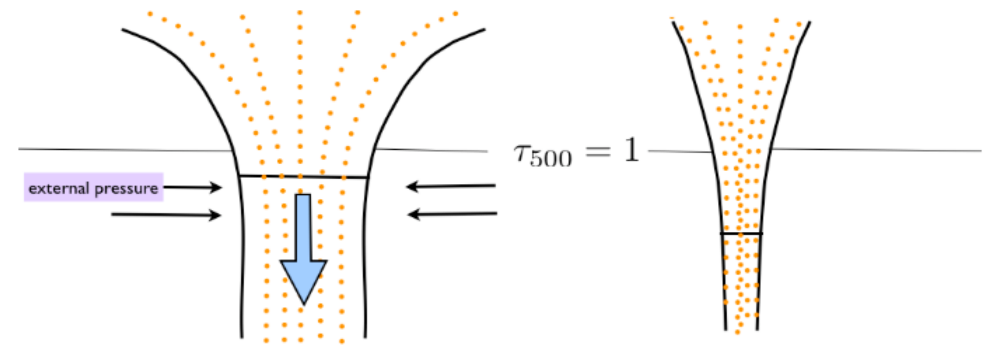
Introduction

Outside of sunspots, a significant amount of magnetic flux is concentrated in small-scale magnetic features. They are mostly transient and are ubiquitous on the solar surface. Small-scale magnetic features are also observed to give rise to a multitude of dynamic events like bombs, jets, bursts etc. Studying the formation, evolution and eventual disappearance of these elements is essential to understand the surface flux budget, and their contribution to upper atmospheric heating.

The aim of the QUEST (Quiet-sun Event STatistics) project is to perform a statistical analysis of the dynamics of quiet-sun, small-scale magnetic features. Of particular interest to us, currently, is the investigation of convective collapse and magnetic flux cancelation events. Convective collapse describes intensification of magnetic field resulting from convective instability. And magnetic flux cancelation describes flux removal from the surface resulting from collision between two opposite polarity magnetic features.



Three possible flux removal processes



Convective collapse

Method

First, we have to do a co-registration of data from different instruments to ensure that the chosen data sets are co-spatial and co-temporal. Our next step is to identify individual magnetic features based on magnetic field/flux and area thresholds. An automatic code based on multi-level magnetic field thresholds is used to identify and tag these magnetic features. We then track them over time using spatial coincidence. Different criteria are employed to distinguish between merging, splitting, and isolated features.

Once the individual features are tracked and tagged, we then identify opposite-polarity pairs to study cancelation events. We start by looking for opposite-polarity magnetic elements, whose boundaries are within a certain distance, to choose them as pairs. An opposite polarity pair is chosen as a canceling pair if the total magnetic flux of either of the polarities or that of both decrease over time.

And for convective collapse events, we use another set of criteria that would choose features that undergo field intensification. Magnetic elements whose field strength rise from below 700 G and reaches up to 1 kG or more are chosen for our analysis. These features must also be accompanied by strong downflows.

A sample frame before and after tagging and tracking is shown here:

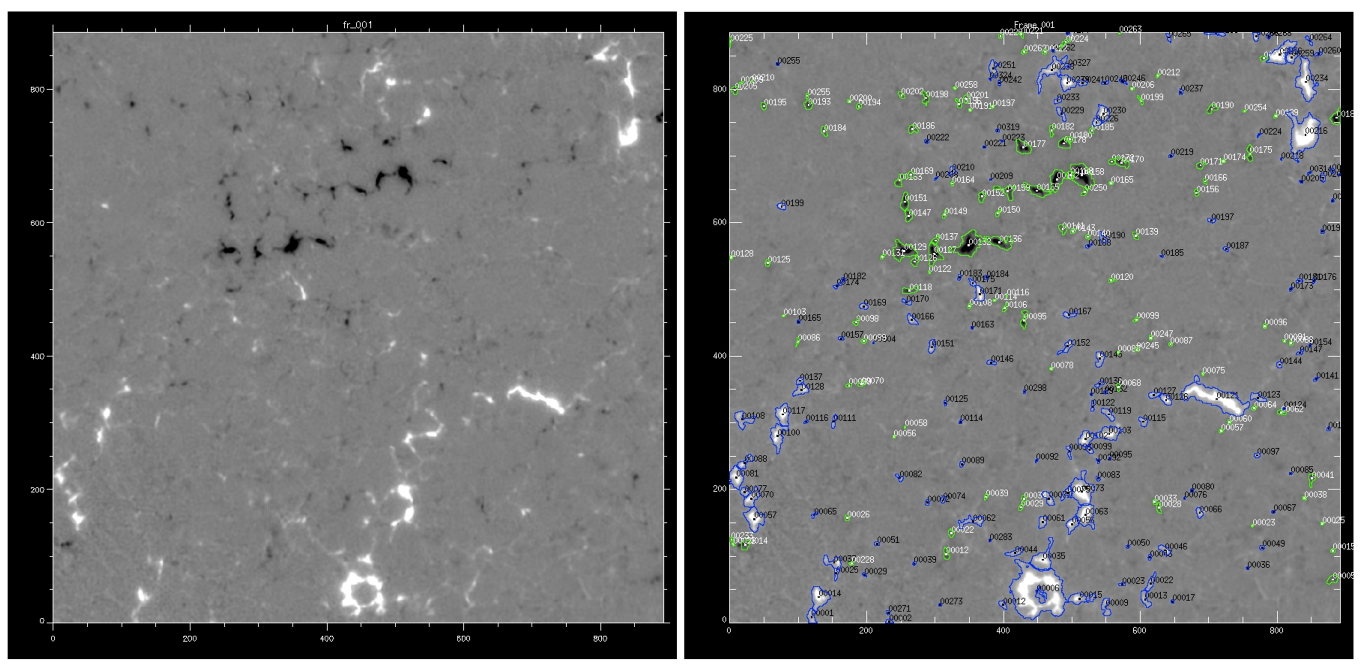
SST/CRISP data (thanks S. Criscuoli) -- quiet-sun disk center

integrated Stokes V map

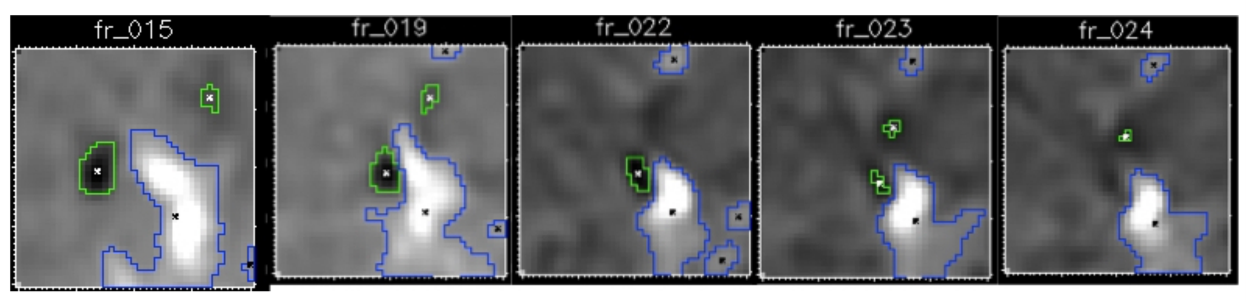
Pixel scale : 0.059 arcsec

FOV – 53” x 53”

Cadence – 28 sec



A sample cancelation event



Positive polarity patches in blue and negative polarity patches in green contours. Asterix represents Stokes V weighted COG position of the patch.

Summary

This identification and tracking method does return reasonable results. However, this method is limited by our choice of thresholds and criteria we employ for tracking, and also the code needs tweaking for different datasets. We plan to use machine learning code in the future to identify and track the small-scale magnetic elements to study their dynamic evolution. We are also interested in learning how machine learning code can be used to derive horizontal plasma velocity on the solar surface.

Acknowledgements

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