

## Studies on homologous flares at quadrupole magnetic field using force-free field modeling

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Solar flares are known as abrupt energy release events by magnetic reconnection. The standard 2D model of solar flares, which is called CSHKP model, explains large eruptive flares well. We analyzed three M-class flares occurring on 2 February 2014, which are difficult to understand with the CSHKP model. Our investigations primarily focused on the 3D coronal magnetic field structures formed in the flaring region for attempting to understand why three similar flares (labeled flare 1, flare 2, and flare 3, respectively) are successively produced in the region.

Four flare ribbons were observed at the footpoints of three flaring structures by Atmospheric Imaging Assembly aboard the *Solar Dynamics Observatory*. The observed flare ribbons and coronal flaring structures show similarity in the three flares, which are called homologous flares. The flare ribbons were located in the four magnetic regions (P1, P2, N1, and N2) at the solar surface. We derived the three dimensional magnetic field configuration using force-free field modeling with *Hinode*/Spectropolarimeter data. We used the squashing factor defined by Titov (1999) to identify the location of quasi-separatrix layers, i.e., QSLs. The magnetic field lines from the force-free field modeling give fairly good correspondences among many bright flare kernels in the flare ribbons, although we still need to improve the modeling fidelity. The magnetic field lines rooted on the flare ribbons forms the three-dimensional quadrupole magnetic configuration with an X-shape separatrix structure in the upper atmosphere.

The region of the highest squashing factor is located at the height of 2000~3000km from the photosphere, suggesting that the magnetic reconnection may take place at the lower atmosphere. The magnetic flux in the N1 sunspot appears to be highly twisted, because the QSLs structure derived with the assumption of the potential field is completely different from what obtained with 3D magnetic field configuration from the NLFFF modeling. The QSLs structure derived with the NLFFF results for the SP data taken one day before the occurrence of flare 1 is different from that derived with the data taken one hour before flare 1. This indicates that the QSLs structure was formed during the day due to the emergence or the transverse photospheric motions of the magnetic flux in N1. The temporal evolution of magnetic flux suggests that both the existence of emerging activities and the converging motions in and around the N1 sunspot region. Focused on homology and differences in the flares, although the spatial distribution of the flare ribbons is similar to each other in the main period of the flares, there is a little difference in the temporal evolution of X-ray flux. Such a difference might attribute to the difference in triggering the onset of these flares. Flare 1 occurred after the occurrence of another flare event at the east side of the flare 1 region, while flare 2 occurred after the upward motion of a dark material. This may indicate that the magnetic field shows a similar topology, but the trigger mechanism can alter the temporal behaviors of the energy release.

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