

# A Study on the Characteristics of Magnetic Field Structure and Evolution of Flaring Solar Active Regions

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Solar flares and coronal mass ejections (CMEs) are energetic, explosive transient events releasing enormous amounts of energy due to sudden destabilization of magnetic field structures in the active regions (ARs). Large flares and CMEs are primary causes of space-weather disturbances including failure of satellites, disruption of communication and power systems etc. Therefore, there is a need to better understand the underlying physics and the associated phenomena theoretically and observationally in these eruptive events and to refine the prediction capabilities, which would help in taking precautionary/preventive measures.

This research work during PhD focuses on the magnetic field structure and its evolution in ARs launching significant number of eruptions in the form of flares and coronal mass ejections. We used continuous time sequence magnetic field observations at the photosphere from *Helioseismic and Magnetic Imager* (HMI) with the complementary multi-layered information from *Atmospheric Imaging Assembly* (AIA) on board space-borne Solar Dynamic Observatory.

The Sun's dynamic evolution is solely due to magnetic flux emergence and their surface motions. These are the prime factors involving the eruptions to store the magnetic energy gradually in AR magnetic system. On following the evolution of two ARs that produced major active events, we found a dominant influence of flux motions over their emergence leading to complex structural evolution in terms of helicity injection. In another detailed study of AR with conspicuous rotating sunspots, we found a well correspondence of physical rotational motion of sunspot with that of magnetic twist profiles indicating the generation of complexity in the magnetic structure of the AR. Following that, the step-down decrease of free-energy at the start times of flares is another major finding that reinforces the energy storage and release picture during solar flares. Further, we studied the coronal magnetic fields of ARs by the model of force-free approximation and found that the model reproduces the topological connectivity in resemblance to coronal plasma tracers. Employing this model, we found in another detailed investigation, the existence of coronal null point associated with fan-spine topology and accumulated current layers at separatrices during X1.5 flare.

As soon as the magnetic system of the AR has reached a state of sufficiently adequate energy, its sudden release requires a suitable triggering mechanism to drive the eruption. In this connection, we investigated the triggering mechanisms of eruptions in ARs. A case of filament eruption involving flux rope structure was found to agree with many features in the standard model of eruption. Furthermore, magnetic field measurements have been found to be affected by emission during the peak phase of the X-class flares. With the availability of spectral data, we deliberately discovered spectral line reversal from absorption to emission. Following this we infer that the field measurements during impulsive phase of X-class flare are not real, and cautions the interpretations on their derived parameters.

Please find the full thesis at [ftp://ftp.iiap.res.in/vemareddy/thesis/vema\\_thes.pdf](ftp://ftp.iiap.res.in/vemareddy/thesis/vema_thes.pdf)

## Publications resulted from this thesis

1. Magnetic Structure of Solar Active Region NOAA 11158  
**P. Vemareddy**, A. Ambastha, and T. Wiegmann, *Bull. Ast. Soc. Ind.*, 2013, 41
2. On the Role of Rotating Sunspots in the Activity of Solar Active Region NOAA 11158  
**P. Vemareddy**, A. Ambastha, R. A. Maurya, *ApJ*, 2012, 761, 60

3. On the Injection of Helicity by Shearing Motion of Fluxes in Relation to Flares and CMEs  
P. Vemareddy, A. Ambastha, R. A. Maurya, and J. Chae, *ApJ*, 2012, 761, 86
4. Velocity and Magnetic Transients Driven by the X2.2 White-Light Flare of 2011 February 15 in NOAA 11158  
R. A. Maurya, P. Vemareddy and, A. Ambastha, *ApJ*, 2012, 747, 134
5. Filament Eruption in NOAA 11093 Leading to a Two-Ribbon M1 Class Flare and CME  
P. Vemareddy, R. A. Maurya and A. Ambastha, *Solar Phys.*, 2012, 277, 337
6. Kinetic and Magnetic Helicities in Solar Active Regions  
Maurya, R. A., Ambastha, A., and Vema Reddy, 2011, *J. Phys.: Conf. Ser.*, 271, pp.012003.