*Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles*
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# Connection between Active region complexity and Solar Flare strength

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**Abstract.** Hale (1908) discovered the existence of magnetic fields in sunspots, and since then a consensus has been reached that magnetic fields play an important role in various forms of solar activities, such as solar flares . Modified Mount-Wilson scheme is one of the methodology to classify active regions based on their complexity . As per this scheme, sunspots are classified as $\alpha$, $\beta$, $\gamma$, and $\delta$ with the complexity of the magnetic topology increasing from $\alpha$ to $\delta$. The $\delta$ sunspots are known to be highly flare-productive. An existing automated algorithm (SMART-DF) is modified and used to identify $\delta$-spots for the existing full disk SOHO/MDI data. The automatically identified $\delta$-spots is compared with the NOAA-SRS database and found to be reproducing almost all the identified $\delta$-spots. In thisstudy, the connection between formation of $\delta$-spot and flares is also carried out using GOES flare flux and NOAA-SRS sunspot classification.

**Keywords.** sunspots, flares

## 1. Introduction

A sudden eruption of intense high-energy of radiation from the sun is called solar flare. Exactly when and where on the solar disk a flare gets triggered is unpredictable. It is important to forecast a flare, both time and position on the disk, for better space weather predictions. The evolution of the magnetic field topological structure is believed to result in the transport of magnetic energy from the solar interior to the surface, and then storage of magnetic energy in the corona. Hence establishing and quantifying this connection between AR complexity with flare is important.

## 2. Data

NOAA releases daily Solar Region Summary (SRS) with area and magnetic classification of each Active region (AR). We studied every AR that caused at least one flare from 2000-2015. X-ray flux of each flare was taken from Geostationary Operational Environmental Satellite System (GOES) catalogue. SOHO-MDI full disk image of intensity and line-of-sight magnetogram from 2000-2010 are used to identify $\delta$ spots apart from NOAA-SRS.

## 3. Results

• Figure 1 shows the ratio of flare produced spots to total spots of $\beta$-$\gamma$-$\delta$, $\beta$-$\gamma$, and $\beta$.About 85 % of $\beta$-$\gamma$-$\delta$ ARs, 73 % of $\beta$-$\gamma$ ARs, and 41 % of $\beta$-spots produced at-least one flare.This means $\delta$ spots have more probability to produce flares and the probability reduces with the complexity reduced.

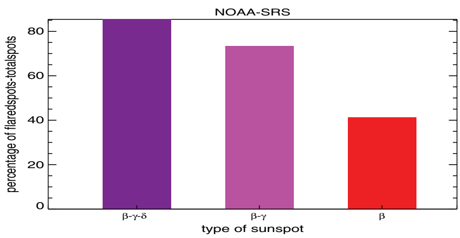


**Figure 1.** Ratio of flared spots to total spots in each type of spot

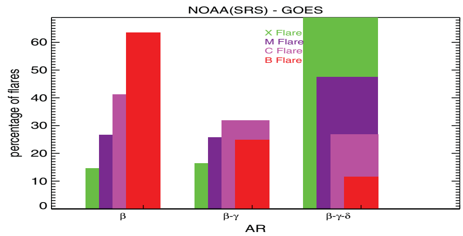


**Figure 2.** Percentage of different flares emitted by $\beta$,$\gamma$,$\delta$ spots

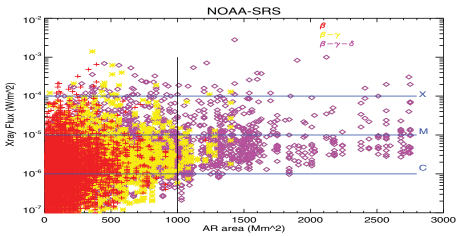


**Figure 3.** AR area VS Xray Flux

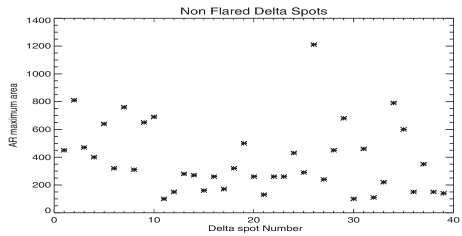


**Figure 4.** Non flared $\delta$ spots

- Solar Monitor Active Region Tracker - $\delta$ Finder (SMART-DF) code Padinhatteeri (2015), is modified to automatically detect $\delta$ spots from MDI data spanning 2000-2010.
- Figure 5 shows During 2000 - 2010, both NOAA-SRS and MDI-SMARTDF code (using only MDI data) detected that nearly 88 % $\delta$ spots were associated with solar flares.

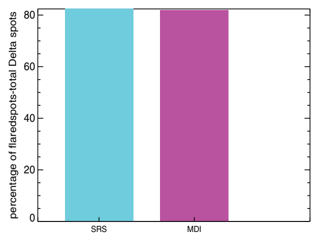


**Figure 5.** % of ARs having a $\delta$-configuration, that lead to flare as detected by SRS and MDI-SMARTDF.

- Figure 2 shows the percentage of different class (B-, C-, M-, and X-class) of X-ray flares produced by the complexity (like $\beta$, $\gamma$, and $\delta$) of spots.It is clear that class of flares and complexity of the active regions are inter-related.
- Figure 3 shows the relation between spots area and X-ray flux of flares. The $\delta$ spots with area more than 1000 M $m^2$ do always produce C-class and above flares. However, $\delta$ spots with small area ($<$ 1000 M $m^2$) do produce all type of flares ($<$ C-class to X-class).
- Hence from figures 3 and 4, it is clear that the complex $\delta$ spot with area $>$ 1000M $m^2$ always produce at least one flare.

## References

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