# Case studies of penumbral formation and decay


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## Observations

- SST/CRISP data: Fe I 630.25 nm, 125 scans on 2016/09/04, and 98 scans on 2016/09/05
- SDO/HMI data: From 2016/09/03 to 2016/09/05, cadence 12 min
- HINODE/SP data: Three raster scan on 2016/09/04 (03:31-03:52 UT), 2016/09/05 (04:03-04:23 UT) and 2016/09/05 (07:17-07:37UT)

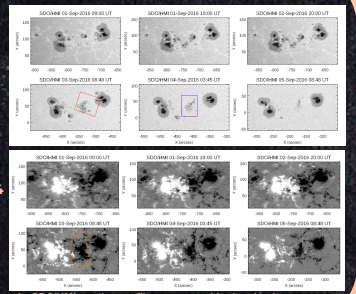
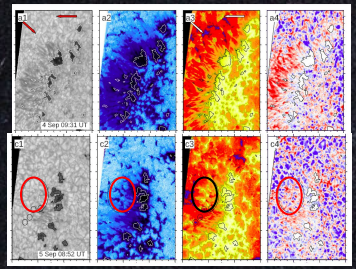


*Fig. 1:* Active Region NOAA 12585 as seen in *SDO*/HMI continuum filtergrams and in the simultaneous LOS magnetograms. The box indicates the studied region.

## VFISV inversion of SST/CRISP data



- Opposite polarity patches associated with bright points before penumbra disappearance.
- Evershed flow only reduced when the penumbra is not visible.
- Sea-serpent-like magnetic configuration of the magnetic appears

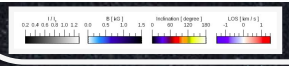


*Fig. 2: From left to right:* Continuum intensity, magnetic field strength, magnetic field inclination, and LOS velocity maps at two representative times on September 4 and 5. .


**Bibliography**

1. Murabito M., Guglielmino S. L., Ermolli I., et al., A&A accepted (2021)
2. Schlichenmaier R., Rezai R., Bello Gonzalez N., A&A 512, L1 (2010)
3. Murabito M., Romano P., Guglielmino S. L., et al., ApJ, 834,76 (2017)
4. Romano P, Frasca D., Guglielmino S. L. et al., ApJ, 771, L3, (2013)
5. Murabito M, Romano P., Guglielmino S. L., et al., ApJ, 825, 75, (2016)
6. Kubo M., Ichimoto K., Shimizu T., et al., First Results from Hinode, 397, 79, (2008)


## Abstract


High-resolution ground-based SST/CRISP spectropolarimetric observations, complemented with data from the space SDO/HMI and HINODE/SP instruments, allow us to investigate the photospheric magnetic and velocity properties of solar plasma in a sunspot penumbra during formation and decay phases. The observed penumbral formation occurs only on one side of the studied region. This preferential location appears to be due to the absence of an overlying magnetic canopy. Then, the studied penumbra disappears gradually in both time and space. The progressive disappearance of different penumbral sectors seems to be linked with the presence of overlying canopies. Noticeably, we detect Evershed flows and horizontal fields after the apparent disappearance of the penumbral sectors.


## Main results

**Penumbral formation** only occurs in the AR region towards opposite polarity, in contrast with some previous observations[2], but as already reported in the literature[3] .

**Penumbral decay** occurs gradually. We found opposite polarity patches associated with penumbral bright points. These are also seen during the penumbra formation process[4] and are observed to move away from the spot[5]. The bright features are correlated with subsurface upwelling and diverging flows[6]. The penumbra does not decay as whole, but different penumbral sector disappear progressively.

## Conclusions

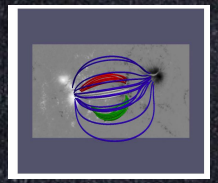


*Fig. 5: Potential field extrapolation obtained using SDO/HMI LOS magntogram taken on September 3 at 08:48 UT as boundary condition.*

- Our observations suggest a key role of the interaction between opposite polarity field (type III MMFs) and penumbral field in the formation and decay processes.
- Field extrapolations support our interpretation of the observed appearance of the penumbra only towards the opposite polarity region and of its gradual disappearance in sectors.

## Spectropolarimetric View

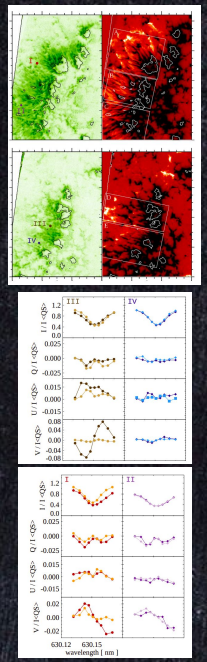


*Fig. 3: From top to bottom: LP and CP maps.The coloured symbols (I-V) refer to location considered in the two bottom panels. Stokes I, Q, U, and V profiles in the pixels (I-IV). The colors indicate initial (dark colours symbols) and final (light colours symbols) times of observations.*

## Magnetic Flux Evolution

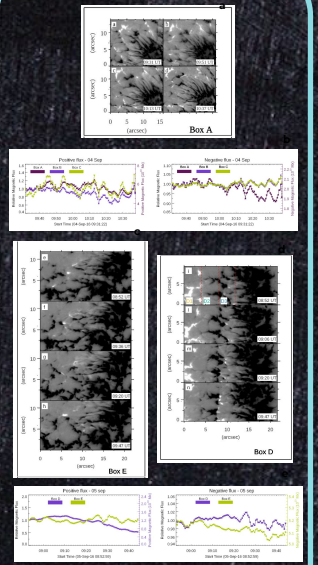


*Fig. 4: Panels a-c-d: Zoomed Cp maps of the SST/CRISP data at four representative times on September 4 and 5. Panels b and e: Evolution of the positive (left panels) and negative (right panels) magnetic flux inside the zoomed panels as derived from the VFISV inversions.*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