High-resolution observations of a δ spot hosting a C4.1 flare

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δ spot generalities

- δ spots
  sunspots with umbrae of opposite polarities inside the same penumbra

- Photospheric properties
  - Strong shear flows are often observed along the PIL of flaring δ spots (Denker & Wang 1998)
  - Curved penumbral filaments, almost tangential to the sunspot umbra: indication of highly twisted (sheared) magnetic field lines

- Many of the strongest flares occur in δ spots (90%, McIntosh 2014)
AR NOAA 11267

An active region containing a $\delta$ spot
## AR NOAA 11267 – August 6, 2011

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Channel</th>
<th>Spectral points</th>
<th>Pixel size (arcsec)</th>
<th>Time resolution (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SST</td>
<td>CRISTP Fe I 5576 Å</td>
<td>20</td>
<td>0.0592</td>
<td>28</td>
</tr>
<tr>
<td>SST</td>
<td>CRISP Fe I pair 6302 Å</td>
<td>15+15 (pol)</td>
<td>0.0589</td>
<td>28</td>
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<tr>
<td>SST</td>
<td>Ca II H core and WB</td>
<td>-</td>
<td>0.0338</td>
<td>9</td>
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<tr>
<td>XRT</td>
<td>Al mesh, Al thick, T poly, Be thick</td>
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<td>1 – 2</td>
<td>20</td>
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<tr>
<td>SDO</td>
<td>HMI continuum</td>
<td>-</td>
<td>0.5</td>
<td>720</td>
</tr>
<tr>
<td>SDO</td>
<td>HMI magnetograms</td>
<td>-</td>
<td>0.5</td>
<td>720</td>
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<tr>
<td>SDO</td>
<td>HMI Dopplergrams</td>
<td>-</td>
<td>0.5</td>
<td>720</td>
</tr>
<tr>
<td>SDO</td>
<td>AIA intensities</td>
<td>304 171 193 335</td>
<td>0.6</td>
<td>12</td>
</tr>
<tr>
<td>Rhessi</td>
<td>3-6 keV; 6-12 keV, 25-50 keV</td>
<td>-</td>
<td>4</td>
<td>- (from 09:00 UT)</td>
</tr>
</tbody>
</table>
At the time of the SST observations AR NOAA 11267 was 2-days old
- Classified as $\beta\gamma\delta$
- 5 C-class flares during its passage across the solar disk
AR NOAA 11267: global properties

- The yellow band indicates the **CRISP** observing period.
- The vertical lines indicate the flares and their magnitude.
- During the time of CRISP observations the **negative** magnetic flux (blue symbols) is in a decreasing phase.
- The **positive** flux is almost constant (red symbols).

The analyzed time interval corresponds to SDO/HMI longitudinal magnetograms acquired from 00:00:00 UT on August 5, 2011 to 23:59:59 UT on August 7, 2011.

SST High-resolution observations + SDO/HMI

Characterization of the plasma properties of the δ spot observed during the post-flare phase
CRISP/SST: data analysis

Indication of the location of up/downward motions along the δ spot PIL

Ca II H: chromosphere (inverted colors)

Motions not related with the chromospheric brightenings: ribbons during the gradual phase of the flare...

Here is the δ spot !!!

--- Part of SST FoV selected for SIR inversion
--- FoV of the figures displayed in the right panel
--- FoV of the zoomed region
CRISP/SST: velocity along the $\delta$ spot PIL

- Velocity map obtained from the Gaussian fit of the Fe I 557.6 nm line
- Clear evidence of strong upflows and downflows along the $\delta$ spot PIL
- The temporal behavior of the velocity in squares (9 x 9 pixels) A and B are reported in the plot
- The trend reported indicates persistent up/downflows in the regions analyzed
- Velocities measured in squares A and B reach up to +/- 3 km/s
- In SDO/HMI, such LOS motions around the $\delta$ spot PIL lasted for almost 15 hours
Maps from SIR inversion of CRISP data

Horizontal velocity field
LCT on Ca II H wideband images

Highly sheared field lines
Analysis of the C4.1 flare observed in the δ spot

Guglielmino et al., in progress

SDO/AIA + SDO/HMI + XRT + Rhessi + SST High-resolution observations
The strongest flare observed during the lifetime of the AR

Timing: 08:37 – 08:47 – 08:51 UT

SST and Rhessi began observations at 09:00 UT
SDO/AIA: the C4.1 flare in NOAA 11267
**SDO/AIA: ribbons evolution**

- Time slices show asymmetries and delays in the evolution of the flare ribbons

- The extruding structure is first observed in the hottest AIA lines, while in the 211/193/171 lines has a peak simultaneous to a dimming in the 304 line at 09:00 UT

Dimming in the chromosphere
**XRT/Hinode: light curves**

- **T\_decay XRT Be thick = 8.73 sec**
- **T\_decay Goes 0.5 – 4 Å = 8.06 sec / Goes 1 – 8 Å = 4.47 sec**
**Rhessi and Blue/SST information**

**red** contours: **Rhessi** 3-6 keV  
**green** contours: **Rhessi** 6-12 keV  
**black** contours: **Rhessi** 25-50 keV  

**yellow** contours: **SST Ca II H isophotes**
Blue/SST: evolution during the gradual phase
Conclusions

- Observations of persistent downflows and upflows observed with CRISP (40 minutes) and HMI (15 hours) along the δ spot PIL

- The magnetic field is highly sheared in this region, where a filamentary structure is wrapped around the negative polarity

- AIA observations of the flare occurring in δ spot indicate that:
  - the C4.1 flare originates above the the δ spot PIL
  - three ribbons are formed, with a Y-shaped structure

- Time slices show a dimming in the chromosphere after the flare

- The bulk of the X-ray emission seems to be located near the crossing point of the Y-shaped structure

- These results have to be compared with the thick target model
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