Rapid Changes of Magnetic Fields Associated With Six X-Class Flares and Halo CMEs

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Summary

• For all six events, leading magnetic flux had a rapid increase after flares.
• Following polarity flux either decreased slightly or unchanged.
• Three events showed new sunspot area, predominantly in the form of penumbra. The same three events had increased transverse fields and magnetic shear.
• Explanation: Emergence of sheared, inclined flux rope or expansion of sunspot associated with flares/CMEs.
Introduction

• In general, there has been no detectable changes of magnetic fields after flares (Chen et al., 1994, Hagyard et al., 1999)
• Some studies showed magnetic shear increase after flares (Wang et al, 1994, Ambastha et al., 1993)
• Magnetic transient and sudden decrease of magnetic flux after a flare/CME (Kosovichev and Zharkova, 2001)
• Sudden magnetic flux increase after flares (Wang and Tang, 1993, Spirock et al., 2002)
• In addition to rapid changes, gradual flux emergence, cancellations, shear motion associated with flares/CMEs have been observed for many events (too long to list)

Observations

• New Digital Vector Magnetograms at BBSO
• MDI magnetograms
• Full disk and high resolution Halpha movies
• Yohkoh HXT and GOES Soft X-ray Observations to indicate flare times
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

Events

<table>
<thead>
<tr>
<th>Date</th>
<th>Start Time</th>
<th>Peak Time</th>
<th>AR No.</th>
<th>Size</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>03/22/91</td>
<td>2230UT</td>
<td>2247UT</td>
<td>6555</td>
<td>X9.0</td>
<td>S23E20</td>
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<td>04/02/01</td>
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<td>2151UT</td>
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<td>X20</td>
<td>N19W75</td>
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<td>1921UT</td>
<td>9415</td>
<td>X5.6</td>
<td>S20E31</td>
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<td>1645UT</td>
<td>9591</td>
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<td>1959UT</td>
<td>9672</td>
<td>X1.2</td>
<td>S18E16</td>
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</tbody>
</table>

August 27, 1990 Flare (Wang, 1992)

Fig 9. A comparison of the weighted mean shear angle with the GOES X-ray flux for the area covering two major footpoints. The large increase of the shear at about 21:00 UT coincides with the onset of the flare, as shown by the jump of X-ray flux.
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

March 22, 1991 (Wang & Tang, 1993)

Spirock et al. (2002)
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

01-10-19 X1.6 Flare

22 March 2002

Big Bear Solar Observatory
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

22 March 2002
Big Bear Solar Observatory

2001/10/19 00:18

STOKES V

2001/OCT/19 16:00:11

Dr. Haimin Wang, BBSO/NJIT (ITP Solar Magnetism Program 3/21/02)
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

Before Flare

After Flare
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

01-08-25 X5.3 Flare
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

22 March 2002

Big Bear Solar Observatory

2001-08-25

2001/08/25 00:42
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

2001-08-25 TRACE Images

22 March 2002
Big Bear Solar Observatory
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

01-10-22 X1.6 Flare
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

22 March 2002
Big Bear Solar Observatory

NOAA 9672, H-ALPHA
2001/10/22 16:19:05

22 March 2002
Big Bear Solar Observatory

2001/10/22 00:18

Dr. Haimin Wang, BBSO/NJIT (ITP Solar Magnetism Program 3/21/02)
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares
### Summary of Results

<table>
<thead>
<tr>
<th>Date</th>
<th>CME</th>
<th>dT</th>
<th>dP (10^{20} Mx)</th>
<th>dF (10^{20} Mx)</th>
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<tbody>
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### Summary of Results (2)

<table>
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<tr>
<th>Date</th>
<th>Magnetic Shear</th>
<th>Transverse Field</th>
<th>New Spot</th>
<th>Explanation</th>
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<td>Increase</td>
<td>Yes</td>
<td>Flux Emergence</td>
</tr>
<tr>
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<td>No vector Data</td>
<td>No</td>
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<tr>
<td>04/06/01</td>
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<td>No vector Data</td>
<td>No</td>
<td>Expansion of p-spot</td>
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<tr>
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<td>Increase</td>
<td>Yes</td>
<td>Flux Emergence</td>
</tr>
<tr>
<td>10/19/01</td>
<td>Increase</td>
<td>Increase</td>
<td>Yes</td>
<td>Flux Emergence</td>
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<tr>
<td>10/22/01</td>
<td>No change</td>
<td>No change</td>
<td>No</td>
<td>Expansion of p-spot</td>
</tr>
</tbody>
</table>
Possible Explanations

1. New Flux Emergence
   - Sheared
   - Inclined
   - Cancellation of New P-flux with Existing F-flux

2. Expansion of P spot

Explanation 1:
New Flux Emergence
Rapid Changes of Photospheric Magnetic Fields Associated with CMEs and Flares

Explanation 2: Expansion of the sunspot

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