

RHESSI 50-100keV 2005 May 13 16:41:34 - 16:42:34 UT

The images indicate that this was a typical two ribbon flare that developed in a bipolar magnetic configuration. The east ribbon was located in an area of negative magnetic fields (black), while the west ribbon was associated with a positive polarity main sunspot. This sunspot showed a strong spiral structure with a left-handed twist, indicating negative helicity. The flare was associated with strong H a emission from two ribbons as well as with four RHESSI hard X-ray sources (S1, S2, S3 and S4) detected in 50-100 keV energy band. Contours show RHESSI HXR emission integrated between 16:41:34 and 16:42:34UT.



Flare Light Curves

RHESSI HXR time profiles (thin lines) and Ha emission (thick lines) calculated over the areas covered by the RHESSI sources.

The flare started at about 16:31UT and the evolution of all H α time profiles is similar. GOES behaved in a quite similar way: its gradual rise began at 16:30UT and it peaked at 116:57UT, about at the same moment as the peaks in Ha. HXR emission from S3 was relatively week and is not shown in this graph. The lower curve is the time derivative calculated from Ha S4. This time derivative corresponds very well to the HXR profiles implying that chromospheric plasma heating and subsequent emission was caused by fast electrons accelerated at the reconnection site.

This simple structure of flare emission as well as similarity between H α and RHESSI time profiles as well as the fact that the time derivative coincides in time with the position of the HXR peaks, all indicate that the flare emission was due to a single reconnection process.

Horizontal Flows from BBSO Magnetograms



Averaged flow map calculated from 107 BBSO magnetograms (15:43 - 19:44UT, r.m.s.=300 m/s). White box shows the position of HXR S1 and S2; CLN and CLS are converging lines of plasma flows, diamond marks the saddle point in the flow and FN and FS are areas where the northern and southern filaments end. S1 and S2 were associated with negative polarities Nf1 and Nf2, while S3 and S4 with positive fields Pf1 and Pf2.

The flow pattern in the vicinity of the major neutral line has two major components: converging and shearing flows. CLN and CLS are tributary lines where oppositely directed flows merge. CLN does not coincide with the main neural line and has a northward component, while CLS has a southward component.

These converging and shearing motions may be indicative that strong helical magnetic fields could form at the major neutral line as suggested by van Ballegooijen & Martens (1989) and further explored by Linker et al. (2005) and Welsch (2005).

Continuation of SHINE Campaign Studies: Eruption on May 13, 2005

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SHINE encourages detailed studies of selected "campaign" events that may help advance our understanding of magnetic energy storage and release mechanism and initiation and evolution of coronal mass ejections (CMEs). One of the SHINE events is the May 12, 1997 eruption. It is a key event in several collaborative campaigns such as SHINE-GEM-CEDAR, MURI, and CISM studies. It is, therefore, appears to be essential to continue these focused, event oriented studies. Many simulations, methods, inferences and theoretical ideas which arose from this campaign study could be tested against observations. The problem is that very important and key data sets were not available (yet) for the May 12, 1997 event. Those include, high resolution and high time cadence vector and/or longitudinal magnetograms (MDI, BBSO), Halpha and white light data (Global Halpha Network, ISOON, TRACE) and hard X-ray data such as provided by RHESSI. Although a solar flare is not a laboratory experiment, and thus can not be exactly reproduced, on May 13, 2005 the sun provided us with an opportunity to observe another eruptive flare, which was very similar to the SHINE May 12 1997 event and,





15:43 UT BBSO vector magnetogram resolved for 180 deg ambiguity (left) and distribution of electric current density calculated from this vector magnetogram (right). Black/white corresponds to +/- 9000 A m^2. Positive currents are upward. Contour lines show RHESSI HXR.

This AR had a relatively simple magnetic configuration with a smoothly varying vector field. The main spot was uniformly twisted counter clockwise. Strongest currents located at two small negative fields SE of the main sunspot and associated with strong converging flows (CLS). The HXR sources (contours) were not associated with strong currents, which agrees with earlier reports (de La Beaujardiere et al. 1993; Leka et al. 1993).

Abramenko et al. (1991, 1993) reported that flare emission, associated with upward currents, was stronger than that associated with downward currents. They concluded that the upward current might provide additional acceleration for electrons traveling down toward the photosphere and thus **Erupting Flux Rope Model for the May 13-15 2005 Event** enhance flare emission in those places. We calculated net current through the area covered by S1 and S2 and by S3 and S4. Thus, electric current imbalance in area S1+S2 was about 20% and the net Krall et al. (2005) showed that the erupting flux rope (EFR) model (Chen & Garren 1993; Chen 1996) current is ~ 2.5x10¹¹ A, while the imbalance in area S3+S4 was about -4% and the net current of could reproduce many details of the CME/ICME event of 2003 October 28-30 and thus provided -4.3x10⁴ A. Because S1 and S2 sources where the most intense and associated with upward net further confirmation of a strong correlation between the magnetic field in an active region and that current, we, therefore, suggest that this upward net current could explain, at least, partially, the in the corresponding ICME (Rust 1994; Yurchyshyn et al. 2001; Hu et al. 2005). Here we further stronger HXR emission from S1 and S2, i.e., asymmetry of HXR emission due to additional investigate this relationship for the 2005 May 13 event in terms of magnetic field structure and Structure of Magnetic Fields in the Corona orientation.





Field lines plotted over an MDI mag-m are calculated from a linear force free model (left, alpha = 0.025) arcsec⁻¹). Filled areas are RHESSI sources S1--S4. Two thick white lines indicate the location of AR filaments. (right:) HXR contours plotted over 12:58UT TRACE 171 image. Inset shows that this magnetic configuration could contain flux ropes suspended above neutral lines and surrounded by large-scale coronal fields.

Three main features can be distinguished in TRACE image: i) a bright rising reverse "S" fields above the FN filament; ii) two bright loop systems Pf1--Nf1 and Pf2--Nf2; iii) two low density voids encompassed by loops Pf1--Nf1 and Pf2--Nf2. These features are reminiscent of the three part structure of CMEs and may indicate a flux rope that exited in the AR prior to the eruption.

Two sets of LFFF lines were chosen by tracing the field lines that originate within the SE part of the sunspot (S3 and S4) and divided into two groups depending on where these field lines end. Thus, S4 source is located at one common footpoint for two independent magnetic fluxes, while their other footpoints were separated and associated with S1 and S2 sources. This inference is supported by the TRACE image which shows that two different loop system are rooted at Pf1 and Pf2 and share common source S4, while their other footpoints, Nf1 and Nf2, were associated with S1 and S2. If so, the four HXR sources could be caused by magnetic reconnection between two sheared loop systems Pf1--Nf1 and Pf2--Nf2.

Converging flows near CLN and CLS could, according to the cancellation model (van Ballegooijen & Martens 1989), lead to formation and strengthening of the Ha filaments suspended above the major NL and to their subsequent eruption. Note that the times scale of flux injection due cancellation process is rather large and thus allows the magnetic configuration to adjust without catastrophic eruptions. We suggest that the eruption was triggered by the emerging magnetic dipole FN--FS. New flux emergence occurs on shorter time scales of order of hours. Therefore, this magnetic configuration could not timely "digest" the high rate of flux injection, which led to stress build-up and subsequent eruption.

May 13 2005 CME first appeared in the LASCO FoV at 17:22UT, it was rapidly expanding with the speed of 1690 km/s. A shock, associated with this ejecta, appeared at 1AU at about 02:00UT on May 15th, while the corresponding magnetic cloud (MC) arrived at about 06:00UT.

This MC had strong Bz (yellow) that was negative at the front edge and slowly turned into positive at in the tail region of the MC. The sign of By (white) and Bx (blue remained the same throughout the Strong and prolonged negative Bz caused an intense geomagnetic storm when the Dst index plunged to -260nT.



ACE MAG magnetic profiles obtained for Bz, Bx and By components of this Interplanetary CME allow us to conclude that this left handed MC was strongly inclined toward the ecliptic plane, its axial field pointed mainly toward East. All these characteristics agree very well with those of the active region that spawned this MC.

EFR model does not address many details of the eruption, i.e. the flux rope is assumed to be present in the magnetic environment at the onset of the eruption. In modeling the 2005 May 13 event, we endeavor to reproduce both the near-Sun CME morphology, dynamics and the timing and characteristics of the near-Earth ICME.



After adjusting input parameters for EFR model such as orientation angles, magnetic flux, temperature, density and drag, the EFR model produced a flux rope with magnetic field (and other) profiles that closely match those observed for the real MC at 1AU (see poster SH13A-0300 for more details).

The orientation, field direction and the twist of the simulated flux rope are the same as these of the active region large scale fields.



A simulated halo CME (left) produced by the EFR model. A top view of the corresponding flux rope is shown in the right image. The orientation of the simulated halo orientation of the plane of the erupting flux rope) was taken from LASCO C3 images for the May13 2005

Comparison between observed ACE data (solid) and the EFR model (dashed)