Major Surge Activity of Super-Active Region NOAA 10484

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Abstract We observed two surges in Hα from the super-active region NOAA 10484. The first surge was associated with an SF/C4.3 class flare. The second one was a major surge associated with a SF/C3.9 flare. This surge was also observed with SOHO/EIT in 195 Å and NoRH in 17 GHz, and showed similar evolution in these wavelengths. The major surge had an ejective funnel-shaped spray structure with fast expansion in linear (about 1.2×10^5 km) and angular (about 65°) size during its maximum phase. The mass motion of the surge was along open magnetic field lines, with average velocity about 100 km s^{-1}. The de-twisting motion of the surge reveals relaxation of sheared and twisted magnetic flux. The SOHO/MDI magnetograms reveal that the surges occurred at the site of companion sunspots where positive flux emerged, converged, and canceled against surrounding field of opposite polarity. Our observations support magnetic reconnection models for the surges and jets.

1 Introduction

During October–November 2003, major solar activity originated from three super-active regions, namely NOAA AR 10484, 10486, and 10488. On 25 October, we observed two surges between 01:50 UT and 04:15 UT that originated from NOAA AR 10484. The first surge was small; the second one was very dynamic and explosive in nature. Using multi-wavelength data we present a morphological study of these surges in order to understand the physical processes behind their activity.

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S.S. Hasan and R.J. Rutten (eds.), *Magnetic Coupling between the Interior and Atmosphere of the Sun*, Astrophysics and Space Science Proceedings,
DOI 10.1007/978-3-642-02859-5_61,

2 Observations

Hα images of these events were obtained at Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, India, on 25 October 2003 using the 15-cm f/15 Coudé solar tower telescope equipped with a Bernard Halle Hα filter, at intervals of 15–20 s and with a pixel size of 1″. We also used data from SOHO/MDI (cadence 96 min, 1.98″ pixels, Scherrer et al. 1995), SOHO/EIT (cadence 12 min, 2.5″ pixels, Delaboudinière et al. 1995), and NoRH (cadence 10 s, 5″ pixels, Takano et al. 1997).

The Hα observations nicely show the dynamic evolution of the recurrent surge activities from 01:50 UT to 04:15 UT (Fig. 1). The surge activities occurred at the following satellite sunspot of the active region. First, a small surge was associated with a small (SF/C4.3) flare, which started at 01:55 UT, reached maximum at 01:57 UT, and ended at 01:59 UT. The arrows show flare 1 and surge 1 in the Hα images. Another subflare (SF/C2.6) then started at 02:59 UT, peaked at 03:00 UT, and ended at 03:07 UT without surge activity. At 03:32 UT, another eruptive subflare (SF/C3.9) started with the second, major, dynamic, and explosive surge. It reached maximum at 03:52 UT and continued up to 04:15 UT. The soft X-ray flux showed two flares during this main surge eruption. The temporal evolution of these 25 October 2003 flares from NOAA AR 10484 is presented in Fig. 2. The surge evolved with initially small velocity, but in the ascending phase its velocity grew and it showed funnel-like structures during its maximum phase at 03:59 UT, which

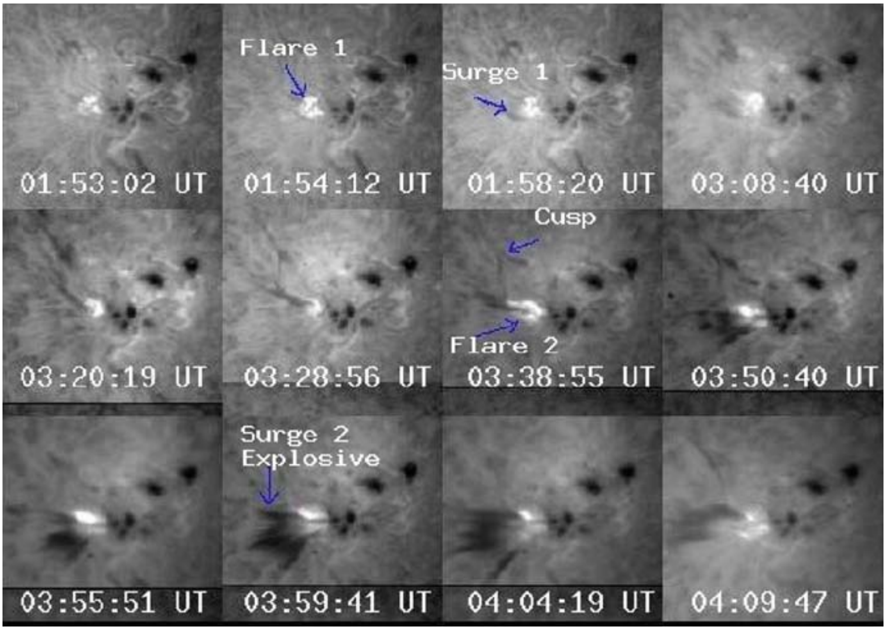

Fig. 1 Sample images of surge evolution in Hα. The field of view is $300'' \times 300''$

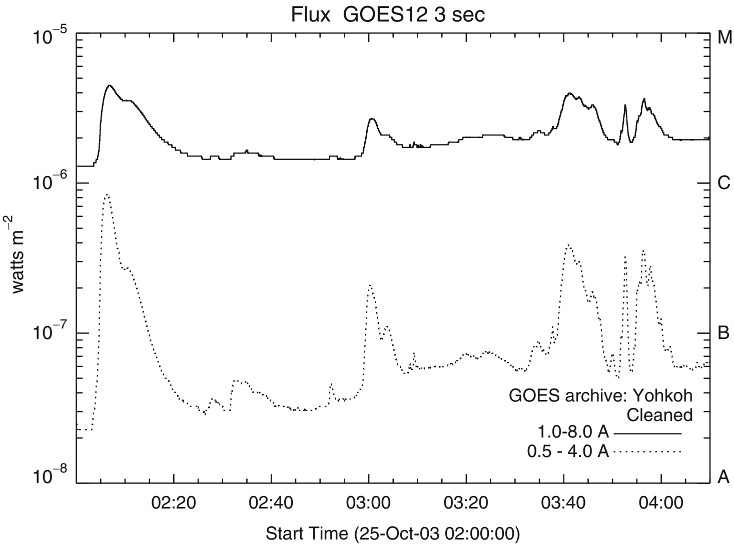

Fig. 2 GOES time profiles of the 25 October 2003 flares from NOAA AR 10484

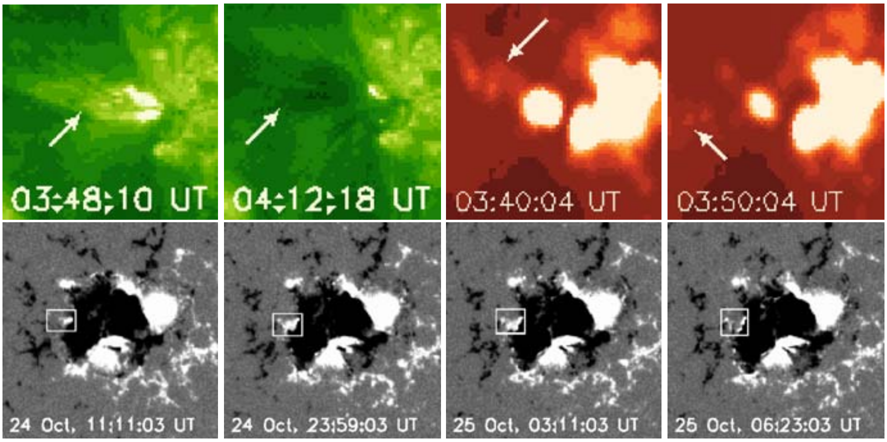

Fig. 3 *Top*: two EIT 195 Å images and two NoRH 17 GHz images showing the surge eruption. *Bottom*: SOHO/MDI magnetograms that show flux emergence and cancelation within the box. The field of view of each frame is $300'' \times 300''$

indicate spray-type behavior (the arrow indicates this explosive surge 2 in Fig. 1). The two-ribbon structure at the footpoint of the surge was also seen during the surge eruption. The Hα movie shows the change in orientation of the surge (from North-East to South-West) and also de-twisting motion was observed during its evolution.

The EIT 195 Å observations show similar morphology of the surge as in Hα: two-ribbon structure and mass motion at 03:48 UT (arrow in Fig. 3). The Nobeyama 17 GHz images also show the orientation change of the surge material as being similar to that in the Hα images at 03:40 UT (Fig. 3).

The MDI observations show positive flux emergence before the 5–6 h of surge activity nearby the satellite sunspot (marked by the box in Fig. 3). This flux emerged before the surge activity and disappeared after the event.

3 Results and Discussion

From our detailed investigation it is evident that the surges were associated with many C-class subflares, which indicates magnetic field annihilation at the site of surge activity. The MDI magnetograms reveal positive flux emergence and its cancelation by surrounding opposite polarity fields. The major surge rose upwards with an average velocity of about 100 km s^{-1}; its orientation change and de-twisting motion demonstrated relaxation of sheared and twisted magnetic field. The funnel-shaped structure of the surge is due to the material that follows the open magnetic field lines at the site (visible in the EIT images). The surge shows similar evolution in Hα (chromospheric temperature), EIT 195 Å (coronal temperature), and Nobeyama radio observations at 17 GHz (nonthermal coronal emission).

These multi-wavelength data indicate that the first reconnection took place between the newly emerged positive polarity sunspot and the pre-existing surrounding field. Subflaring then occurred, plasma was heated up to 10 MK, and transported towards open and closed field lines, which led to the formation of the two small flare loops visible in Hα and EIT, and the funnel-shaped surge structures. This scenario was earlier reported by Yokoyama and Shibata (1995) on the basis of numerical simulations. The flaring loops that formed nearby the footpoint of the surge and the type-III radio burst that was observed during this event are evidence favoring the magnetic-reconnection surge model (Shibata et al. 1994, Schmieder et al. 1995, Canfield et al. 1996). Our observational results support this model of magnetic reconnection for surges. These are only the preliminary results; we are planning to carry out more detailed study of these observations.

Acknowledgment We thank the conference organizers for a very good meeting and the editors for excellent instructions. R.C. thanks the CIFIPRA for his postdoc grant.

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