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LETTERS

Three Super Active Regions in the Descending Phase of Solar Cycle 23 *

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Abstract We analyze the magnetic configurations of three super active regions, NOAA 10484, 10486 and 10488, observed by the Huairou Multi-Channel Solar Telescope (MCST) from 2003 October 18 to November 4. Many energetic phenomena, such as flares (including a X-28 flare) and coronal mass ejections (CMEs), occurred during this period. We think that strong shear and fast emergence of magnetic flux are the main causes of these events. The question is also of great interest why these dramatic eruptions occurred so close together in the descending phase of the solar cycle.

Key words: Sun: activity — Sun: flares — Sun: magnetic fields

1 INTRODUCTION

It is well known that solar activity exhibits an 11-year periodicity, and the more dramatic activities usually occur in the maximum of the cycle. The complicated dynamics of magnetic fields plays a key role in the course of the activities (Parker 2001). It is commonly accepted that the maximum of solar cycle 23 is near June 2000. However, three super active regions (ARs) NOAA 10484, 10486 and 10488, appeared in 2003, between October 18 and November 4, and produced many unexpected eruptive events. These events (flares and CMEs) led to severe effects on the Earth, such as power blackouts, disruption of communications, and damage to satellites.

At the Huairou Solar Observing Station (HSOS) of the National Astronomical Observatories of China, we carried out systematic observations (see Table 1) of these three ARs with the MCST (Ai & Hu 1986; Deng et al. 1997), dedicated for vector magnetic field observation. The working lines of the MCST are FeI λ5324.19Å for photospheric, and Hα and Hβ for chromospheric observations. The observational data provide a unique opportunity for investigating the evolution of magnetic nonpotentiality and for examining how this evolution is related to explosive events.

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Table 1 List of Observations of Three Active Regions at HSOS

Date	Time (UT)	Measure	Date	Time (UT)	Measure
18	03:00–08:00	L, T, V, Hα, Hβ	26	00:00–06:00	L, T, V, Hα, Hβ
19	23:00–01:00	L, T, V, Hα, Hβ	27	01:00–06:00	L, T, V, Hα, Hβ
20	00:00–02:00	L, T, V, Hα, Hβ	28	00:00–08:00	L, T, V, Hα, Hβ
21	01:00–04:00	L, T, V, Hα, Hβ	29	00:00–08:00	L, T, V, Hα, Hβ
22	00:00–09:00	L, T, V, Hα, Hβ	30	00:00–05:00	L, T, V, Hα, Hβ
23	00:00–07:00	L, T, V, Hα, Hβ	31	03:00–05:00	L, Hα
24	00:00–09:00	L, T, V, Hα, Hβ	02	05:00–07:00	L, T, V, Hα, Hβ
25	00:00–08:00	L, T, V, Hα, Hβ	03	03:00–07:00	L, T, V, Hα, Hβ

L: Longitudial field; T: Transverse field; V: Doppler velocity field.

2 DATA ANALYSIS

2.1 Active Region NOAA 10484

Figure 1 shows a series of vector magnetograms in the active region NOAA 10484. This region had a delta configuration, and was located at N04 L355 on the solar disk. Some 2 X-class, 16 M-class and 28 C-class X-ray flares occurred in this region. A highly sheared transverse magnetic field formed near the magnetic neutral line. We can clearly see that the transverse field near the negative polarity sunspot A rotated counterclockwise between October 22 and 25. The bright kernels of Hβ flares are shown in Fig. 1.

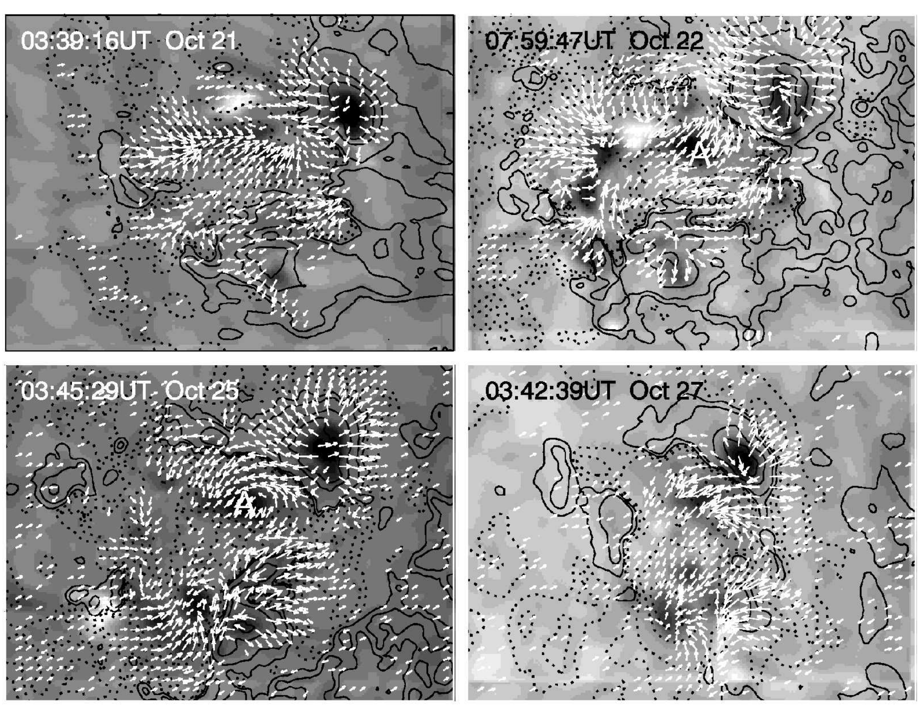

Fig. 1 Photospheric vector magnetograms in NOAA 10484. The solid (dashed) contours indicate the longitudinal field of positive (negative) polarity. The arrows mark the transverse field. The magnetograms of the AR are overlaid with the Hβ filtergrams. The field of view is $3.75' \times 2.81'$. North is at the top and west is to the right.

2.2 Active Region NOAA 10486

The active region NOAA 10486 was located at S17 L283 and passed through the solar disk from October 23 to November 4. Seven X-class flares, including the biggest solar flare (X-28) seen in recent years, and 15 M-class flares occurred in this region. From the vector magnetogram shown in the upper panel of Fig. 2, we can see that the highly sheared transverse field rotated clockwise around the sunspot with positive polarity along the magnetic neutral line. The lower panel of Fig. 2 shows an Hα flare overlaid on the vector magnetogram. The bright kernels of the flare are near the magnetic neutral line.

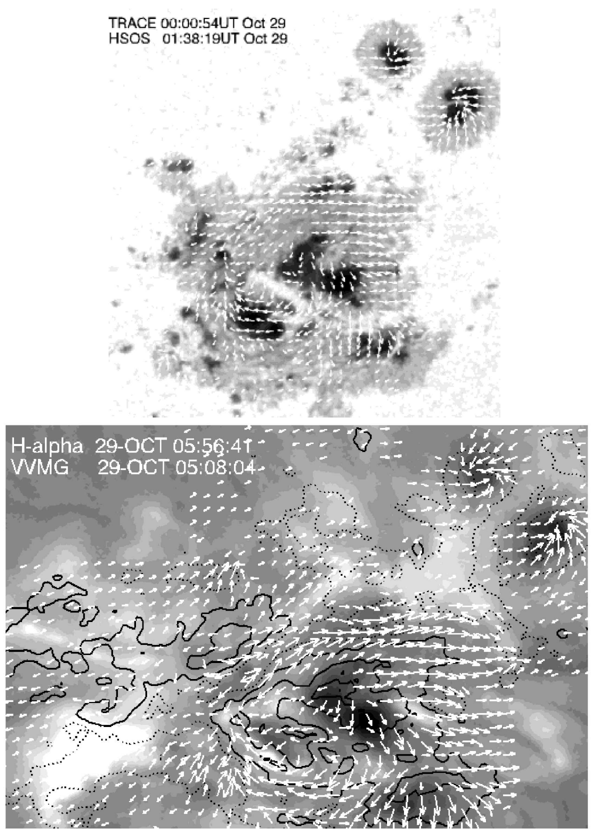

Fig. 2 Photospheric vector magnetic field in NOAA 10486. The solid (dashed) contours indicate the longitudinal field of positive (negative) polarity. The arrows mark the transverse field. The magnetograms of the AR are overlaid with a TRACE white light (upper) and Hα (lower) image. The size of the lower image is $4.0' \times 2.7'$.

2.3 Active Region NOAA 10488

Figure 3 shows a series of photospheric vector magnetograms of the active region NOAA 10488. This region began to emerge on October 25 and grew rapidly to a large AR on October 27; it was a fast emerging flux region. We can see some magnetic islands of opposite polarity being gradually formed in the middle of the AR. Simultaneously the main spots rotated clockwise. The AR produced several flares and CMEs during its disk passage. On November 3, from 9:35 UT to 10:21 UT, an X-2.7 flare was observed. And a large CME was observed by LASCO C2 at 10:55 UT.

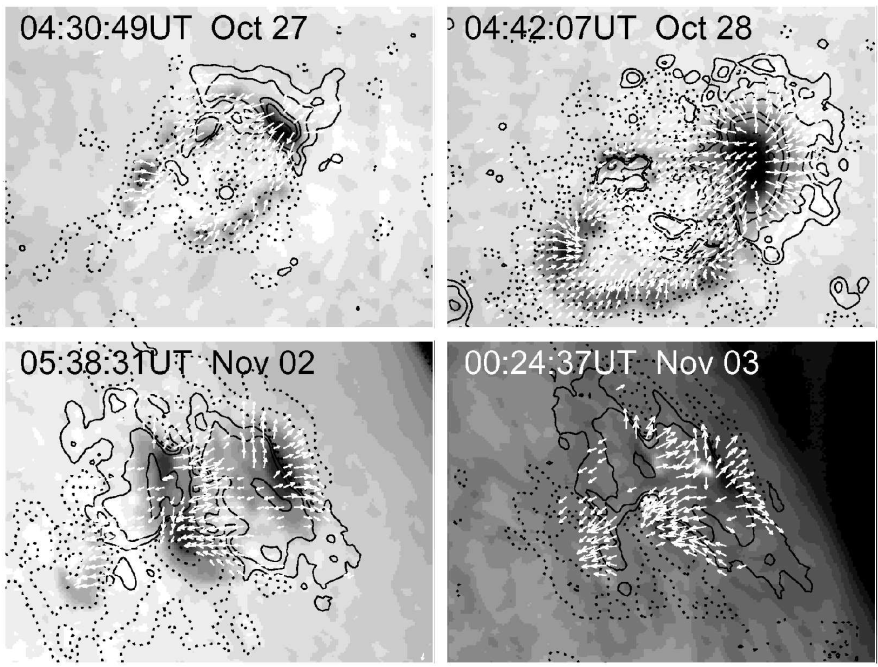

Fig. 3 Photospheric vector magnetograms in the emerging active region NOAA 10488. The solid (dashed) contours indicate the longitudinal field of positive (negative) polarity. The arrows mark the transverse field. The magnetograms are overlaid with the Huairou photospheric images and Hβ (right bottom) image. The field of view is $3.75' \times 2.81'$.

3 CONCLUSIONS

In the descending phase of Solar Cycle 23, some unexpected dramatic eruptive events (such as X-class flares and CMEs) occurred in three super active regions, NOAA 10484, 10486 and 10488. Through analysis of the evolution of magnetic non-potentiality in these regions, we found that NOAA 10484 and 10486 are delta magnetic configurations with highly sheared fields, and that NOAA 10488 is a fast emerging flux region. We conclude that strong shear and fast emergence of magnetic flux are the main mechanisms of these eruptive events. More detailed explanations for these solar activity phenomena are required to further study.

Understanding the cause of these events may help us to forecast increases in the occurrence of energetic solar flares and CMEs, and so help to predict the effects of such eruptions on the Earth and its environment.

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