Proc. of Kofu Symposium, NRO Report No. 360, July, 1994

A MORPHOLOGICAL STUDY OF MAGNETIC SHEAR DEVELOPMENT IN A FLARE-PRODUCTIVE REGION NOAA 7270

H. Kurokawa [1], R. Kitai [1], G. Kawai [1], K. Shibata [2], K. Yaji [2], K. Ichimoto [2], N. Nitta [3], and H. Zhang [4]

[1] *Kwasan and Hida Observatories, Kyoto University, Kamitakara, Gifu 506-13, Japan*

[2] *National Astronomical Observatory, Mitaka, Tokyo 181, Japan*

[3] *Lockheed Palo Alto Research Laboratory, Palo Alto, CA 94304, U.S.A.*

[4] *Beijing Astronomical Observatory, Beijing 100080, China*

Abstract

The evolutional changes of a flare-productive region NOAA 7270 were examined in details with high resolution Hα images, magnetograms and soft X-ray images to study the process of the magnetic shear development and its relation to the strong flare activity of the region. This study led us to the following results and a conclusion:(1) Several new bipolar pairs simultaneously and or successively emerged in NOAA 7270 from 5 through 7 September. (2) Magnetic shear configurations developed at three locations, where most of flares occurred from 5 through 7 , September. (3)These magnetic shear configurations were formed by successive emergences of twisted magnetic ropes from below the photosphere.

1. Introduction

The magnetic shear configuration is considered to be most essential for flare occurrence as many optical observations have shown (Zirin and Tanaka, 1973; Hagyard et al., 1984; Kurokawa, 1987; Wang, 1992). It means that the observations examining how the magnetic shear develops are fundamentally important for us to understand the flare-energy build-up process. Kurokawa (1987) found two types of processes for the magnetic shear development between sunspots from morphological studies of active region evolutions; (A) collision of the sunspots of opposite magnetic polarities, and (B) successive emergence of a twisted magnetic flux rope. And he concluded that the process of the type(B) is responsible for the production of major flares.

On the other hand, optical observations have also revealed that flare occurrences are often related to emerging flux regions, though most of emerging flux regions appear without any conspicuous flare activities. Studying which type of emerging flux region is responsible for the production of strong flares, Kurokawa (1991) concluded that a new flux emergence which makes a strong magnetic shear configuration produces a strong flare activity.

These previous works clearly suggest that more high resolution observations of *shear-developing emerging flux regions* are necessary to understand not only the energy build-up but also the triggering proceses of flares. The NOAA 7270 is one of such regions, because it rapidly grew and produced many flares during a short period from 5 through 7 September, 1992.

2. Observations

Observational data used in this work are high resolution Hα images obtained with the 60cm Domeless Solar Telescope at Hida Observatory, Kyoto University, longitudinal magnetograms by Mitaka, National Astronomical Observatory, vector magnetgrams by Huairou Station, Beijing Astronomical observatory, and soft X-ray images by the Soft X-ray Telescope aboard Yohkoh. The high resolution Hα and sunspot images were most essential to study the evolutional changes of magnetc shear configuration, and the longitudinal magnetograms also played an important role in the determination of the polarity boundary lines. The vector magnetograms and soft X-ray images were used in confirmation of the results obtained from the Hα data. Some of Hα images showing the evolutional changes of the region are found in Figure 1 of Kitai et al. (1994).

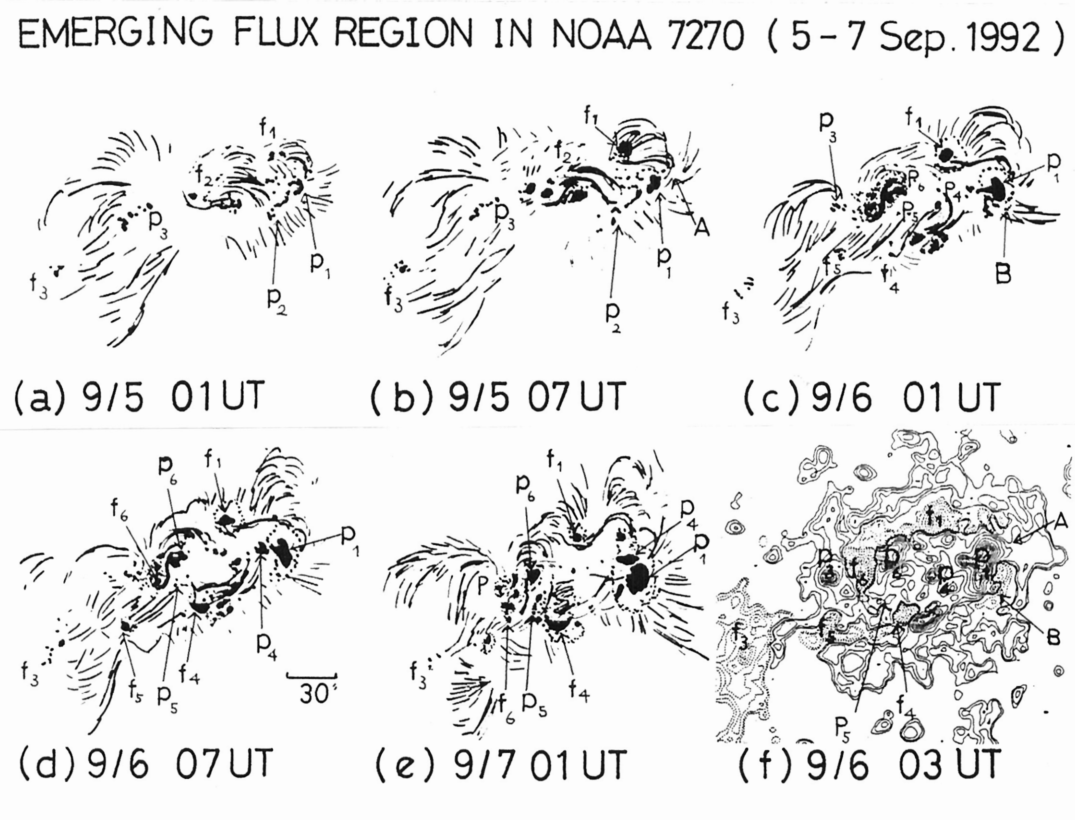

Fig. 1. The evolutional changes of Hα fine structures and sunspots of NOAA 7270 studied by using Hida high resolution Hα images. The six emerging flux regions p_1 - f_1,.....,p_6 - f_6 are found to be growing. Thin lines are Hα dark fibrils and filaments representing directions of the chromospheric transverse magnetic field. The dark spots, dots and dotted circles shows sunspot umbrae, pores and penumbrae, respectively. The map (f) is a longitudinal magnetogram observed by Huailou Station.

3. Morphological Study of Emerging Flux Regions

It is not easy to discriminate which bipolar pair is originally connected below the photosphere or which connection has been made beween different bipolar pairs after their emergence above the photosphere. We made this by examining the evolutional changes of sunspots and Hα fine structures in details for NOAA 7270 region. The result obtained from the examination of Hida Hα images is summarized in Figure 1, where dark and dotted areas, and fine full lines show sunspot umbrae, sunspot penumbrae, and Hα fibrils or filament structures, respectively.

The p_1 - f_1 pair constantly grew from 5 through 7 September. Notice an associated development of sheared Hα filament along the polarity boundary line between the sunspots p_1 and f_1. This means that the magnetic shear between p_1 and f_1 was formed as a result of the continuous emergence of new magnetic flux between p_1 and f_1, or *the successive emergence of a twisted bundle of magnetic loops from below the photosphere.*

The p_2 - f_2 emerging flux region shows Hα arch filament loops only on 5 September, but not any more on the next day. Instead, a more conspicuous and new emerging flux regions p_4 - f_4 and p_5 - f_5 came up on 6 September. The direction of Hα arch filament loops between them is nearly perpendicular to that of the the p_2 - f_2 pair. Such a drastic change of the direction of the emerging magnetic field was also found in the October 12, 1981 flare region (Kurokawa, 1987) and February 3, 1983 flare region, and produced strong magnetic shear configurations and large flare activities.

The p_6 - f_6 pair emerged in an δ-type sunspot configuration and showed a rapid rotation of its bipolar axis to develop a magnetic shear between the sunspots from 5 through 6 September. This type of magnetic shear development is also considered to be formed by *a successive emergence of a compact and twisted magnetic rope* suggested by Tanaka et al.(1980).

4. Discussion and Conclusion

From a detailed examination of the evolutional changes of sunspots, Hα fine structures and longitudinal magnetic fields of NOAA 7270, we found six emerging flux pairs and three flare-active locations, where magnetic shears developed from 5 through 6 September, 1992. The vector magnetograms of Huailou Station also show the transversal magnetic field in the photosphere along the polarity boundary line at these three locations. We conclude that the three magnetic shear configurations are all produced by the successive emergence of twisted bundles of magnetic loops. This conclusion is illustrated by a cartoon in Figure 2, where full lines show the emerging bundles of magnetic loops, and dotted lines show higher and older coronal magntic loops which emerged on the previous day, and shaded patches are sunspot umbrae.

Figure 3 shows the evolutional changes of soft X-ray loops as well as sunspot growth in NOAA 7270 observed with the Soft X-ray Telescope of Yohkoh. The successive growth of coronal loops can be found over the p_1 - f_1 pair from 5 through 6 September. Some cronal loops connecting the p_2 - f_2 pair can be seen on the two frames of 01 UT and 09 UT 5 September, but completely different coronal loops appeared on the next day or on 6 September in the direction nearly perpendicular to that of the the p_2 - f_2 loops. These evolutional changes of soft X-ray loops are consistent to the results obtained from the optical observations discussed above.

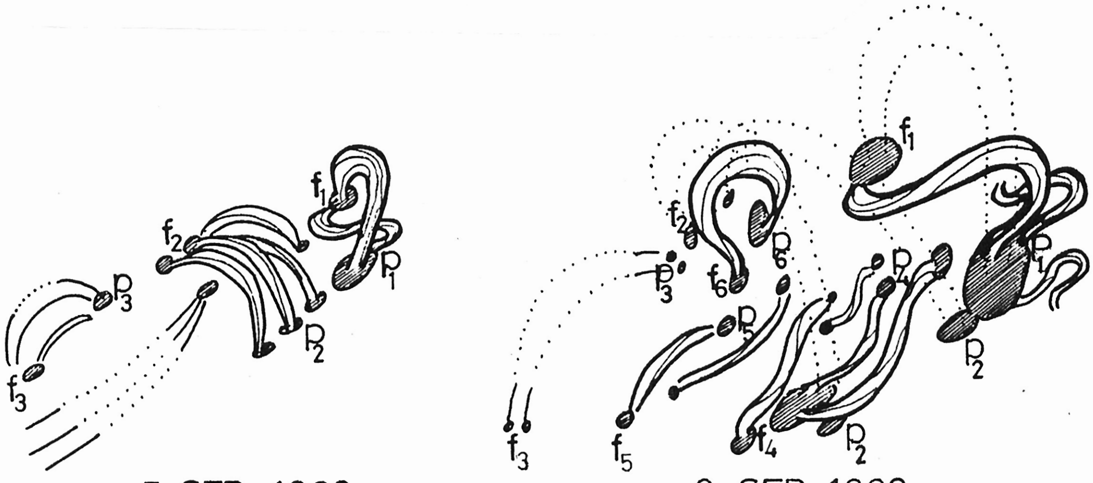

Fig. 2. A cartoon showing the successive emergence of twisted bundles of magnetic loops which produced the emerging flux regions and magnetic shear configurations in NOAA 7270. Full lines show the emerging bundles of magnetic loops, and dotted lines show higher and older coronal lines which emerged on the previous day. Shaded patches are sunspots umbrae.

References

1. Hagyard, M.J., Smith, J.B., Teuber, D., and West, E.A.: 1984, *Solar Phys.* **91**, 115.
2. Kitai, R., Kurokawa, H., Funakoshi, Y., Nakai, Y., Ichimoto, K., Shibata, K., and Yaji, K.: 1994, in T. Sakurai (ed.), *Proceedings of China-Japan Workshop on Solar Physics*, in press.
3. Kurokawa, H.: 1987, *Solar phys.* **113**, 259.
4. Kurokawa, H.: 1991, *Lecture Notes in Physics,* **387**, 39.
5. Tanaka, K., Smith, Z., and Dryer, M.: 1980, in M. Dryer and E. Tandberg-Hanssen (eds.), *Solar and Interplanetary Dynamics, IAU Symp.* **91**, 231.
6. Wang, H.: 1992, *Solar Phys.* **140**, 85.
7. Zirin H., and Tanaka, K.: 1973, *Solar Phys.* **32**, 173.

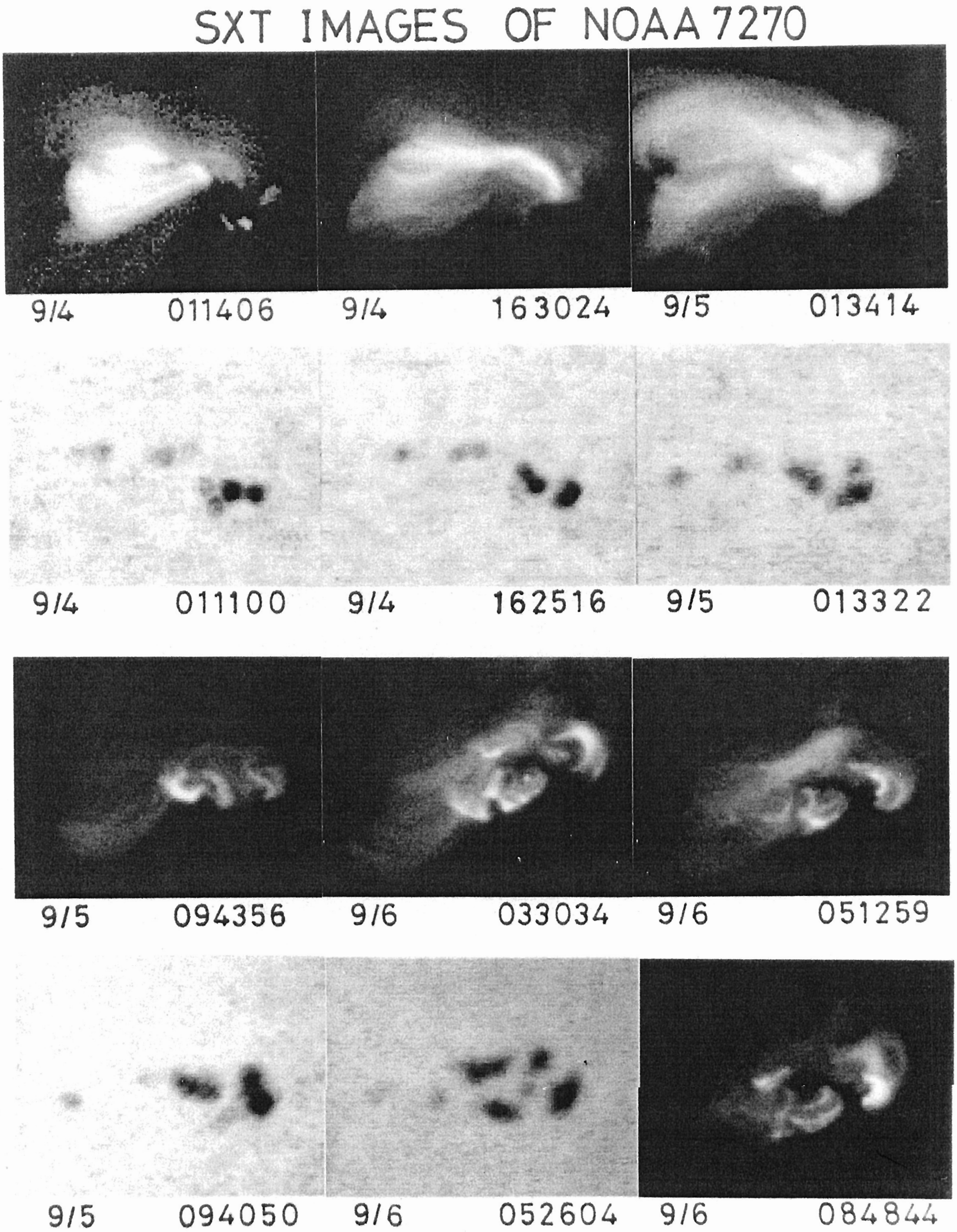

Fig. 3. The evolutinal changes of coronal loops and sunspots in NOAA 7270 observed by the Soft X-ray Telescope aboard Yohkoh.