

## SUN, SOLAR ACTIVITY AND ASTROBIOLOGY

DOI:<http://dx.doi.org/10.18524/1810-4215.2019.32.182447>MULTI-WAVELENGTH OBSERVATIONS OF  
A LARGE SOLAR FLARE

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**ABSTRACT.** We present the results of the multi-wavelength study of the two-ribbon solar flare on July 19, 2000 in the active region NOAA 9087. The evolution and morphological properties of the flare productive active region have been analyzed. The active region was growing rapidly and showed a complex multipolar magnetic field configuration. It was large, producing many events, including the flare under consideration. The 3N/M6.4 two-ribbon flare was a prominent, long duration event in the active region evolution. According to Solar Geophysical Data (SGD) the flare lasted 2.5 hours. The flare energy release took place in many sites of the active region.

We used combination of data from space and ground based observatories for study. The hard X-ray (HXR) and soft X-ray (SXR) data were obtained at the Yohkoh Telescopes (HXT and SXT) and Geostationary Operational Environmental Satellite (GOES). The full-disk magnetograms and EUV-images were provided by the Solar and Heliospheric Observatory (SOHO) Michelson Doppler Imager (MDI) and Extreme ultraviolet Imaging Telescope (EIT). We used the  $H_{\alpha}$  filtergrams from the Meudon spectroheliograph and white light images of Big Bear Solar Observatory (BBSO).

All the data show continuously evolving SXR, EUV and  $H_{\alpha}$  features during the flare. The HXR and the type III radio bursts were observed at the flare onset. The first  $H_{\alpha}$  flare kernels and the surge, connected with the filament eruption, were initiated near a large positive-polarity sunspot. The main bright kernels of the flare occurred at the centre of the active region near magnetic neutral line, after that the flare ribbons appeared along it. It was found that HXR coronal source was located along a magnetic polarity inversion line of the active region. EUV loop structures indicate the observational evidence of a magnetic reconnection during the main phase of the flare.

**АНОТАЦІЯ.** В роботі представлено результати багатохвильового дослідження двострічкового сонячного спалаху 19 липня 2000 року в активній області NOAA 9087. Проаналізовано еволюцію та морфологічні властивості спалахово

активної області. Активна область швидко зростала і демонструвала складну багатополярну конфігурацію магнітного поля. Вона була великою, спричиняла багато подій, включно зі спалахом, що вивчається. Двострічковий спалах 3N/M6.4 був визначною, тривалою подією в еволюції активної області. За даними Solar Geophysical Data (SGD), спалах тривав 2,5 години. Викид енергії спалаху відбувався у багатьох місцях активної області.

Для дослідження використано поєднання даних космічних та наземних обсерваторій. Дані для жорсткого (HXR) та м'якого (SXR) рентгенівського випромінювання були отримані на телескопах Yohkoh (HXT та SXT) та Geostationary Operational Environmental Satellite (GOES). Магнітограми та EUV-зображення були отримані Solar and Heliospheric Observatory (SOHO) Michelson Doppler Imager (MDI) та Extreme Ultraviolet Telescope (EIT). Були використані  $H_{\alpha}$ -фільтрограми з Meudon spectroheliograph та зображення в білому світлі з Big Bear Solar Observatory (BBSO).

Усі дані показують, що під час спалаху відбувалися постійні зміни в різних діапазонах: SXR, EUV та  $H_{\alpha}$ . На початку спалаху спостерігалися сплески HXR та радіосплески III типу. Перші  $H_{\alpha}$ -ядра спалаху та хромосферний викид з'явилися біля великої сонячної плями з позитивною полярністю. Основні яскраві ядра спалаху виникли в центрі активної області поблизу магнітної нейтральної лінії, після чого вздовж неї з'явилися стрічки спалаху. Було встановлено, що корональне джерело HXR розташоване уздовж лінії інверсії магнітної полярності активної області. Структури EUV-петель вказують на спостережні докази магнітного перез'єднання під час головної фази спалаху.

**Keywords:** active regions, solar flares, magnetic reconnections, multi-wavelength observations.

## 1. Introduction

Solar two-ribbon flares are extremely powerful eruptions caused by magnetic reconnections. The magnetic energy is converted into radiation, heat, particle acceleration, fluxes and waves. The development of two-ribbon flares has been studied on the base of multi-wavelength observations in many works (eg, Ding et al., 2003, Rovira et al., 2007, Kumar et al., 2010). They are often accompanied by eruption of the filament lying along the neutral magnetic line (eg, Ding et al., 2003). Surges are observed often simultaneously with two-ribbon flares. Kumar et al. (2010) reported that the trigger of the M8.9/3B flare was the activation of spiral-twisted structures. The emergence of a new magnetic flux, the movement of photospheric matter, the shear and the vortex movements at the footpoints of the loops can lead to magnetic reconnection, resulting in flares (eg, Heyvaerts et al., 1977, Gorbachev et al., 1988, Somov et al., 2002, Su et al., 2007).

We study an evolution and morphological properties of the two-ribbon solar flare on July 19, 2000 in the flare-productive active region NOAA 9087. We used multi-wavelength data and analyzed the sequence of flare images on filtergrams in the  $H_\alpha$  line, magnetograms and extreme ultraviolet images.

## 2. Observational data

Space-born and ground based observations are used. The hard X-ray (HXR) and soft X-ray (SXR) data were obtained at the Yohkoh Telescopes (HXT and SXT) and Geostationary Operational Environmental Satellite (GOES). The full-disk magnetograms and EUV-images were provided by the Solar and Heliospheric Observatory (SOHO) Michelson Doppler Imager (MDI) and Extreme ultraviolet Imaging Telescope (EIT).  $H_\alpha$ -filtergrams were obtained with the Meudon spectroheliograph, radio data with Learmonth Solar Radio Spectrograph, white light images in Big Bear Solar Observatory (BBSO).

## 3. Active region NOAA 9087

Morphological properties of the active region (AR) NOAA 9087 have been analyzed. The active region emerged from the edge of the solar disk on July 15 and was visible on the disk until July 27, 2000. AR developed rapidly, its structure changed. The number of spots increased from day to day, new spots appeared, while others disappeared. The shape of the spots was complex and changed over time. The active region showed a complex multipolar magnetic field configuration, which became more complicated as it developed. Parasitic polarity regions were observed,

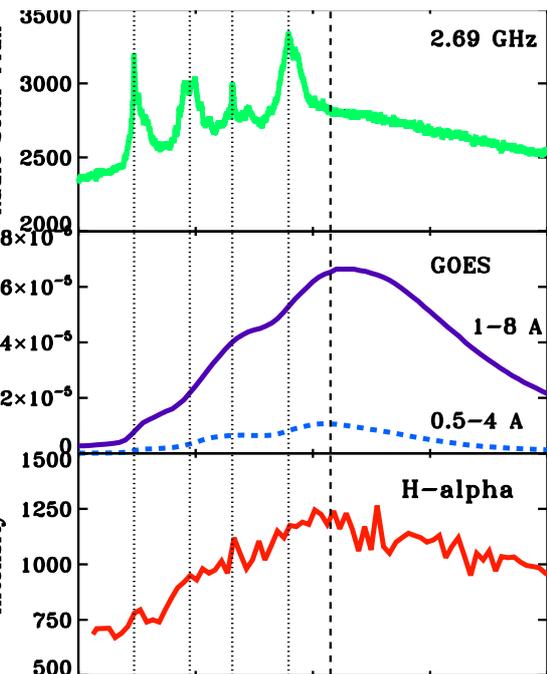


Figure 1: Different wavelength light curves ( $H_\alpha$  intensity, soft X-ray flux, radio solar flux) for flare on July 19, 2000.

which indicates the emergence of new magnetic fluxes. The neutral magnetic line had a curved shape, its length and shape changed in time. The region produced many events, including the flares. Flare activity peaked on July 19, when the magnetic field configuration was  $\beta$ - $\gamma$ - $\delta$ . The most powerful 3N/M6.4 two-ribbon flare in the active region occurred on that day. We analyzed the development of this flare in present work.

## 4. Flare evolution

According to Solar Geophysical Data (SGD) the 3N/M6.4 two-ribbon flare occurred in the active region NOAA 9087 at 06:37 UT on 2000 July 19, peaked at 07:23 UT and lasted 2.5 hours. Flare coordinates are S18E10. The flare is a long duration event. SXR, EUV and  $H_\alpha$  data show continuously evolving features during the flare.

Hard X-ray and the type III radio bursts were observed at the flare onset. Two bursts of the HXR intensity and four radio bursts at 2.69 GHz were in the initial phase (Table 1, Figure 1). Figure 1 shows different wavelength light curves. The flux of soft X-ray radiation slowly decreased in the main phase of the flare. Flare peaks at the  $H_\alpha$  line are later than peaks in radio emission and HXR. It indicates that magnetic reconnections took place in corona at onset of the flare.

We used the observational data in the  $H_\alpha$  line ob-

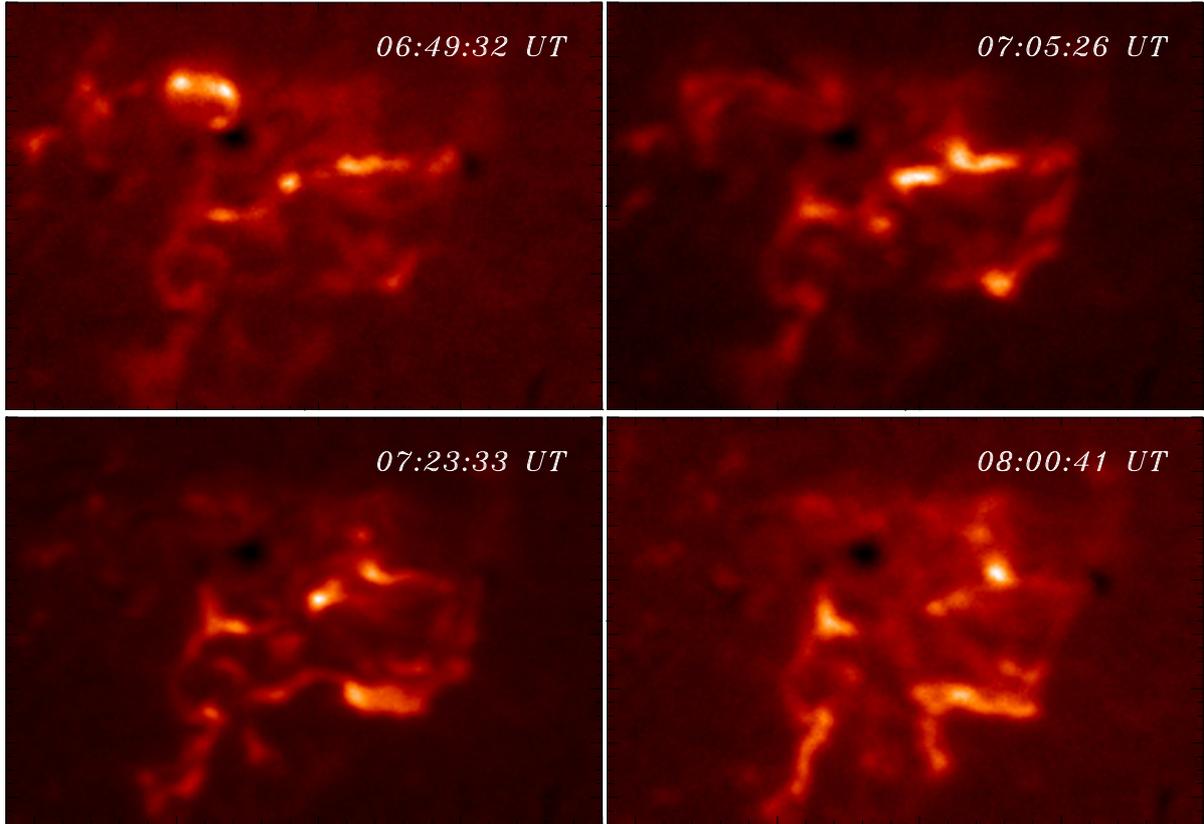


Figure 2:  $H_{\alpha}$ -images (Meudon) for different phases of flare July 19, 2000 evolution

Table 1: Times (UT) of burst peaks in different wavelength ranges.

	Max1	Max2	Max3	Max4
HXR	06:49:27	06:57:01		
Radio	06:49	06:59	07:06	07:16
$H_{\alpha}$	06:50:33	07:01:11	07:07:34	07:18:12

tained using the spectroheliograph of the observatory in Meudon for study. Filtergrams were obtained in time steps from 30 seconds to 1 minute. We have analyzed in detail the development of the flare in  $H_{\alpha}$ -filtergrams. Figure 2 shows the evolution of the flare in the  $H_{\alpha}$  line. At the beginning of the flare two bright kernels appeared in the region of a large spot, several plages and flare kernels brightened at first peaks of HXR and radio emission at 06:49 UT. New flare kernels appeared at the middle part of the active region. The first flare kernels near the large spot disappeared, large post-flare loops appeared and chromospheric surge occurred at this place (Fig. 2).

The position of the hard X-rays source at 06:57 UT

was obtained by Yohkoh HXT. The HXR contour image was overlaid on the MDI magnetogram,  $H_{\alpha}$ , SOHO 195 Å and SXT images (Fig. 3). Comparison between the spatial distribution of the  $H_{\alpha}$  kernels and that of the HXR source shows that HXR source was located in the central part of active region above the magnetic neutral line in the brightest kernel area. In most of the area, the position of the source of hard X-rays coincides with the place of the soft X-ray emission.

A new  $H_{\alpha}$  kernel appeared at the bottom of the active region shortly before the flare maximum. Flare kernels in the other part of the active region brightened. Cold post-flare loops near large spot are visible in 304 Å. The maximum brightness of all kernels was at the main  $H_{\alpha}$  peak of the flare at 07:23 UT (Fig. 2).

A set of consecutive images of loops in the extreme ultraviolet wavelength passband 195 Å was analyzed. EUV loop structures show the observational evidence of a new magnetic reconnection closer to the spot during the main phase of the flare (Fig. 4). New flare  $H_{\alpha}$  kernels appeared in the magnetic reconnection area (Fig. 2).

## 5. Conclusions

The evolution of the two-ribbon 3N/M6.4 flare on 19 July 2000 in the flare-productive solar active region NOAA 9087 analyzed on the base of the multi-wavelength observations, combination of data from space and ground-based observatories. All the data show continuously evolving SXR, EUV and  $H_\alpha$  features during the flare.

The active region was growing rapidly and showed a complex multipolar magnetic field configuration. It was large and produced many eruptive events. The 3N/M6.4 flare was a prominent, long duration event in the active region evolution. The flare energy release took place in many sites of the active region.

HXR and type III radio bursts were observed at the flare onset. The first  $H_\alpha$  flare kernels and the surge were initiated near a large positive-polarity sunspot. The main bright kernels of the flare occurred at the centre of the active region near magnetic neutral line, after that the flare ribbons appeared along it.

HXR coronal source was located above magnetic neutral line of the active region in the brightest  $H_\alpha$  kernels area. EUV loop structures show the observational evidence of the magnetic reconnections during the flare main phase.

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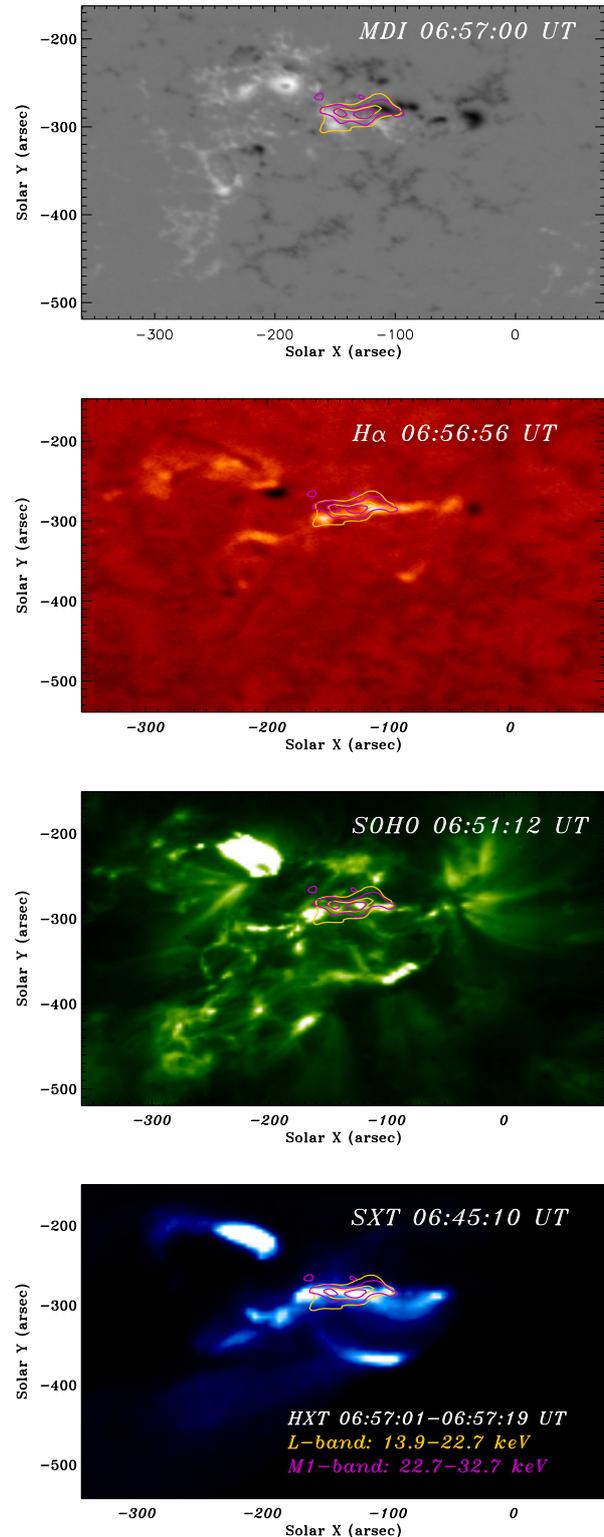


Figure 3: The Yohkoh HXR contour image is overlaid on the MDI magnetogram,  $H_\alpha$ , SOHO 195 Å and SXT images.

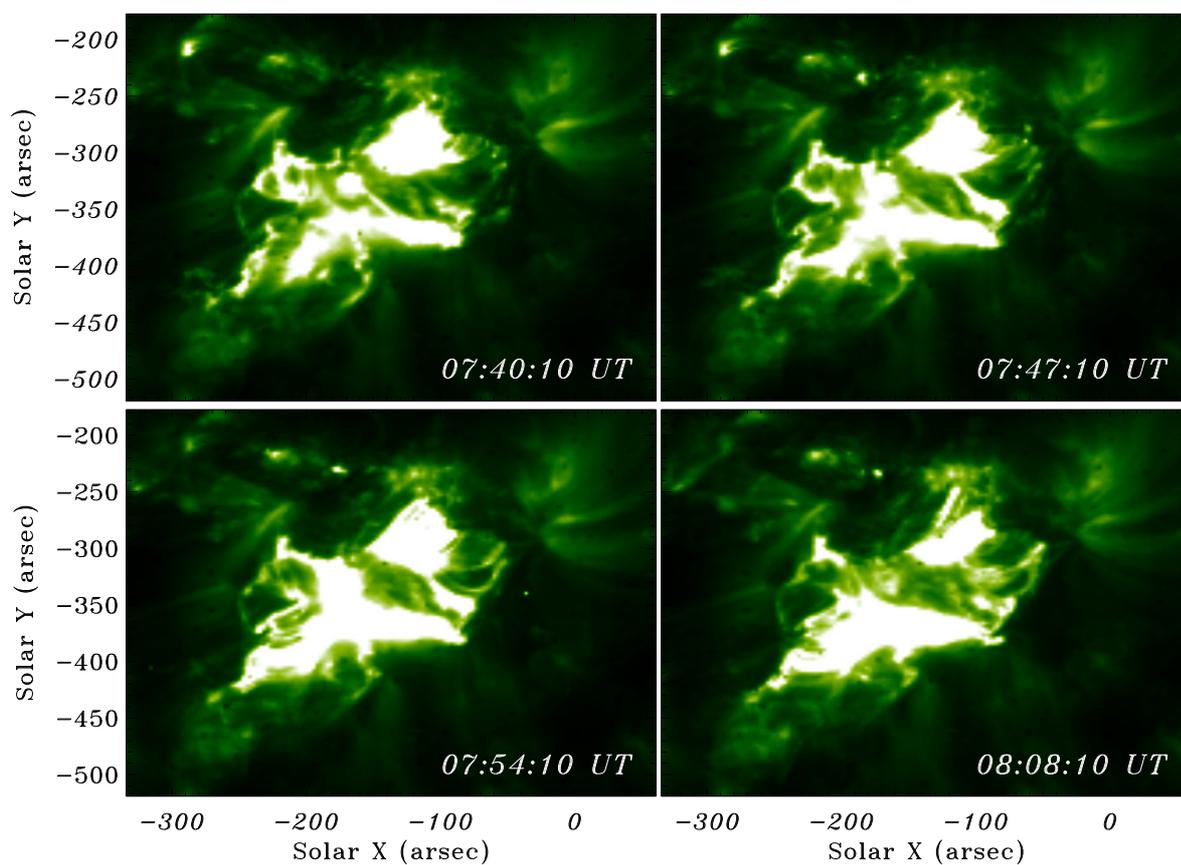


Figure 4: EUV (195 Å) images at different moments of the flare evolution show magnetic reconnections in corona at main flare phase.