RADIO EMISSION ASSOCIATED WITH MASS EJECTION EVENTS FROM ACTIVE REGIONS OF THE SUN - EVENT OF 1992 AUGUST 5

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Abstract

This paper has been realized in the frame of the collaboration of the Wrocław and Nançay investigators. The spray, observed in Wrocław by means of the Small Coronograph, was connected with radio sources observed by the Nançay Radioheliograph. The radio sources were situated in two active regions; the first one - close to the spray and the second one - far from it. The connection between these active regions was confirmed by the YOHKOH-SXT image, where the giant magnetic loop interconnecting them can be seen.

1 INTRODUCTION

Solar flares and other energetic phenomena (for example sprays) observed in H_α appear above an active region (AR) during magnetic field changes in this region. These changes may cause reconnection of magnetic lines above the AR. Spray (SPY) is an example of an active event caused by reconnection.

The energetic solar phenomena observed in H_α are often accompanied by radio bursts usually classified according to their spectra into types from I to V (for reviews see Kundu, [1965]; Zheleznyakov, [1970]). The bursts are observed at metre wavelengths and originate in the corona at or above the heights where the local plasma frequency equals the emission frequency. Since the local plasma frequency depends on the electron concentration of plasma in the generation-site of radio emission, using one of the models of the coronal density distribution, the altitude of the source generating the radio emission can be determined.

Radio sources are usually situated in the corona above an AR in which a flare occurs and they are placed near magnetic structures of this AR. Directly, the localization of

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a radio source can be determined from two-dimensional radioheliograph observations. In our investigation the connection between two remote active regions observed on the 5th of August 1992 is discussed. This connection manifests itself by the appearance of the radio sources above one of them and some optical active events in the second one, simultaneously. This may suggest the existence of a giant magnetic loop connecting these two remote active regions, what was confirmed by the YOHKOH-SXT images. Such large scale X–ray loops in YOHKOH were discussed by Švestka and Farnik [Švestka and Farnik, 1994, and references therein]. However, in our case the giant magnetic loop had existed before the flare occurred.

2 OBSERVATIONS

The spray of August 5, 1992 was observed in H_α by means of the Small Coronograph in Wrocław.

The Small Coronograph has been developed for observing evolution of solar limb activity in the H_α line [Rompolt and Kraus, 1969]. It is equipped with a rather broad-band Hα filter which enables to observe even fast moving material having a large line-of-sight velocity component.

The flare data have been taken from the Table "H_α Solar Flares" of SGD 577-I. Additional data concerning the morphology, the magnetic fields and the activity of the active regions under investigation have also been taken from SGD.

The radio data associated with the optical events observed by us have been taken from the Table: "Radio Bursts Fixed Frequency" of SGD 582-II. Spectral identifications of the radio observations have been done using the Table: "Solar Radio Emission-Spectral Observations" of SGD 578-I as well as the original spectral observations of the Potsdam and IZMIRAN Observatories.

Positions of the radio bursts have been localized using the Nançay Multifrequency Radioheliograph. Since 1991 the Nançay Radioheliograph (NRH) provides two-dimensional control of radio brightness of the Sun with subsecond time resolution on five frequencies chosen anywhere in the range 150-450 MHz (altitude range from 0.1 to $1R_\odot$ above the photosphere) with the restrictions imposed by terrestial interference. The frequencies are observed sequentially during 5 ms, and correlation is performed independently for the east-west and north-south branches. The characteristics of the instrument are summarized in Table 1 [The Radioheliograph Group, 1993].

One of the instruments on board the Japanese satellite YOHKOH [Ogawara et al., 1991] is the Soft X–ray Telescope, SXT [Tsuneta et al., 1991]. It is a grazing-incidence telescope sensitive to 3–45 **r**A X–rays having a CCD detector. Five filters allow to modify the sensitivity to different wavelength regions within this wavelength window. The SXT is able to image each part of the Sun's soft X–ray with a spatial resolution up to 2.45 arc sec and a temporal resolution up to several seconds. The SXT also contains a lens and filtering system for imaging the Sun's white-light onto the same detector.

Table 1: NANÇAY RADIOHELIOGRAPH

Arrays	Number of antennas	Minimum baseline	Maximum baseline	Beamwidth (150 MHz)	Beamwidth (450 MHz)
East-west	19	50 m	3200 m	1.3 arc min	0.42 arc min
North-south	24	54.3 m	1248 m	3.5 - 9.6	1.2 - 3.3

Time resolution: 10 images/second at each frequency
Measurement of circular polarization (Stokes par. V)
Dynamic range: > 45 dB
Observing time: 8:30 to 15:30 UT

3 DESCRIPTION OF EVENTS

Both optical and radio events occurred in or above two active regions of the Sun. The first active region, called hereafter AR I, was situated at the east limb of the Sun on mean position S10. No active region from SGD (see Table: Sunspot Groups, SGD578-I) could be identified with AR I although enhanced bipolar magnetic field was recorded in its place by the Mount Wilson Magnetograph some days later (see SGD 578-I, SGD 579-I and Figure 1).

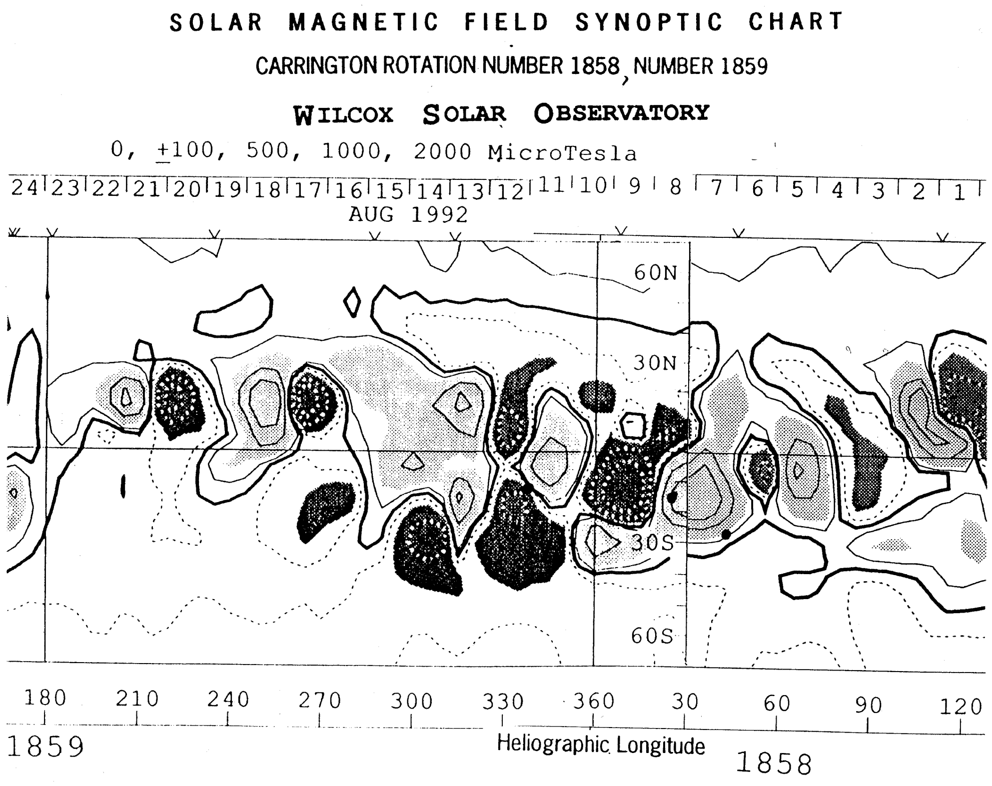

Figure 1: Stanford Solar Magnetic Field Synoptic Map compiled for rotations 1858 and 1859

The second active region, denoted by us AR II, was situated on the disk. It consisted of two close groups: the first one NOAA7248 (its mean position was S12-E34) and the second one NOAA7251 (mean position: S17-E32). The AR II displayed a pronounced activity during its passage across the disk.

On the 5th of August 1992 from 0931 UT to 1023 UT two flares, the spray, and fourteen significant radio bursts were observed in the AR I and AR II or close to them. All these events are presented in Table 2 in the order dependent on their moments of start with the independent numeration for the radio bursts and the flares.

Table 2: SEQUENCE OF EVENTS ON AUGUST 5, 1992

Start (UT)	Event in H_α	No	Burst type	Duration (s)	ν (MHz)	AR	Remarks
09:31:10		1	Cont	20	327.0	II	Radio emission enhancement
09:39:30		2	Cont	120	236.6	II	Radio emission enhancement
09:42:05		3	III	2	236.6	I	Double source of radio emission
09:42:07		4	III	3	164.0	I	Movement down of the source
09:43	F1			400		I	
09:44:40		5	IIIG	6	236.6	I	
09:44:55		6	III+V	25	164.0	I	Movement up of the source
09:44:55		7	Cont	30	236.6	II	
09:45:00		8	IIIG	15	236.6	I	
09:45:01		9	III	18	327.0	I	Source movement along loop
09:45:18	SPY					I	
10:08	F2			900		II	
10:11:13		10	III	4	164.0	II	
10:11:16		11	IIIG	10	236.6	II	Movement down of the source
10:11:17		12	IIIG	4	164.0	I	Double source of radio emission
10:11:20		13	III	15	327.0		Situated between ARI and ARII
10:11:25		14	III	6	164.0		Situated between ARI and ARII

The orthogonal coordinates of the radio burst sources have been calculated using the east-west baseline recordings of the Nançay Multifrequency Radioheliograph as well as the north-south ones (example recordings are given in Figure 2).

The positions of all the radio burst sources as well as flares and the spray are shown in Figure 3 as projected on the composite picture of the Sun's soft X–ray made by YOHKOH.

The heliographic latitude of the spray on the east solar limb has been determined by us. The coordinates of the flares have been taken from SGD.

At 09:31:00 UT at 327 MHz the enhanced radiation of type Continuum was registered near AR II (the source of this radio emission is called hereafter (1); the next radio burst sources are marked in the same way). This enhancement lasted for about 20 seconds. Some time later at 09:39:30 UT, the second radio burst (2) of type Continuum started in the corona near the AR II at 236.6 MHz. It lasted about two minutes. Next, two type III bursts were recorded above the AR I. The first one had started at 09:42:05 UT at 236.6 MHz and its source (3) showed double structure. The second one had started at 09:42:07

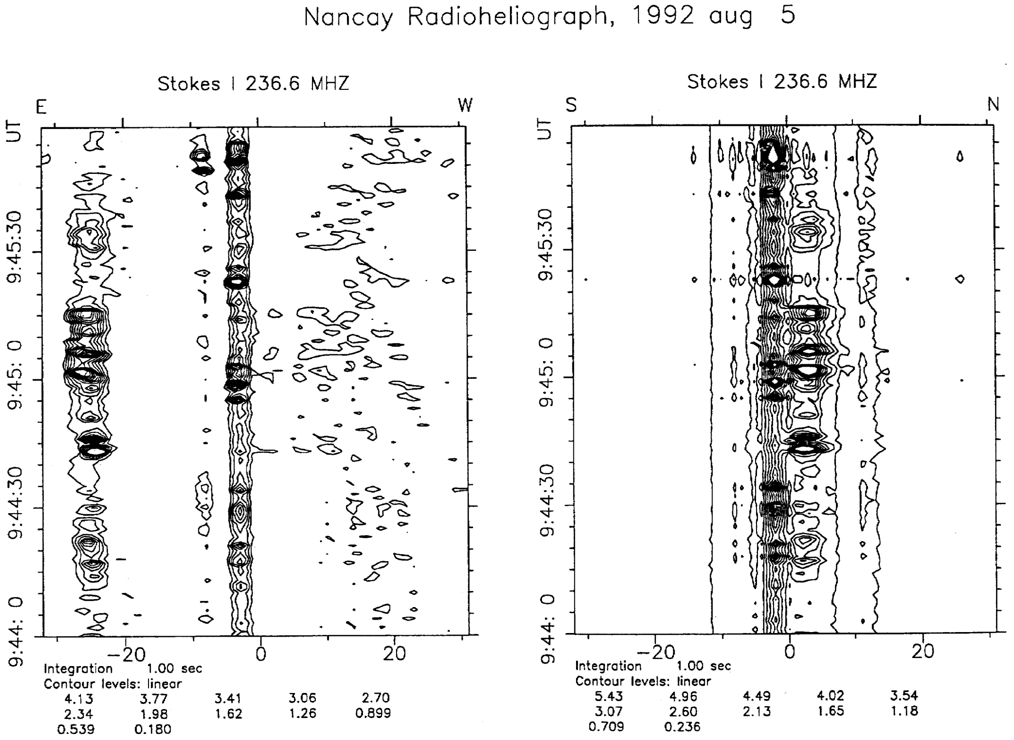

Figure 2: Example recording of the investigated radio bursts taken with the Nançay Radioheliograph. Contours of equal brightness are shown with the position projected onto the terrestrial east-west (left) and south-north (right) baselines along the abscissa, time along the ordinate. Position "0" denotes the center of the solar disk.

UT at 164 MHz and its source (4) exibited some movement (see Figure 3b). After that during the period 0943-0950 UT the flare F1 of importance SN appeared in the AR I (see SGD 577-I). According to the GOES, F1 was seen in X–ray emission from 0940 UT to 0952 UT and its importance was B 9.5. Throughout this flare the next type IIIG burst (5) appeared above the AR I at 236.6 MHz at 09:44:40 UT. At 09:44:55 UT the type III+V burst was recorded at 164 MHz above the AR I and its source (6) indicated some movement upwards. Simultaneously with (6) the Continuum (7) at 236.6 MHz (lasting 30 seconds) was observed above the AR II. At 09:45:00 UT the next type IIIG bursts: (8) at 236.6 MHz and (9) at 327 MHz occurred above the AR I. Similarly to (6) the source (9) showed some movement upwards. Soon the spray (SPY) was ejected from the AR I and was followed to a height of $50 \cdot 10^3$ km above the photosphere. The spray had been recorded from 09:45:36 UT to 09:47:48 UT, its start may be deduced from the H-T diagram as 09:45:18 UT (see Figures 4 and 5), but its real end, unfortunately, was not observed.

Some time later the second flare F2 of importance SF developed on the disk in the AR II. It lasted from 1008 UT to 1023 UT and according to the GOES data its maximum importance in X–ray emission was C 1.0. During the flare development five sources of type III radio bursts could be identified in turn. At first the radio burst (10) was recorded at 10:11:13 UT at 164 MHz and next (11) at 10:11:16 UT at 236.6 MHz above the AR II. The source (11) had split in time into several components and was recorded on the

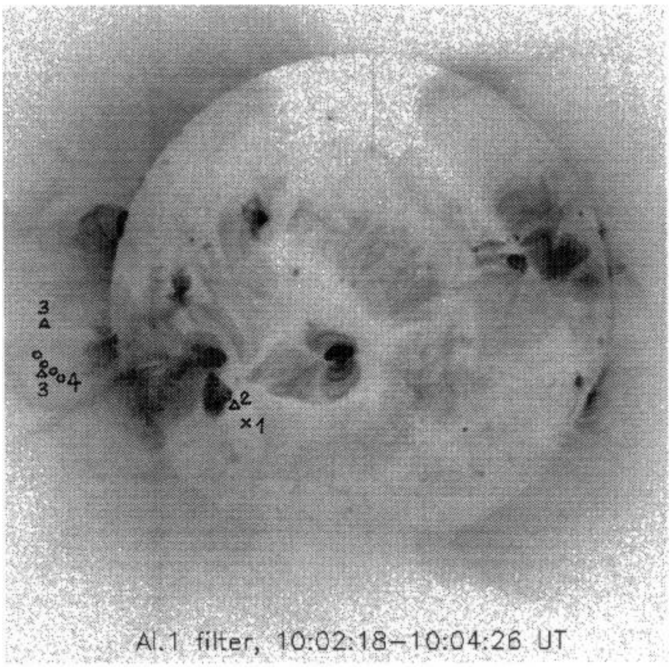

Figure 3a:

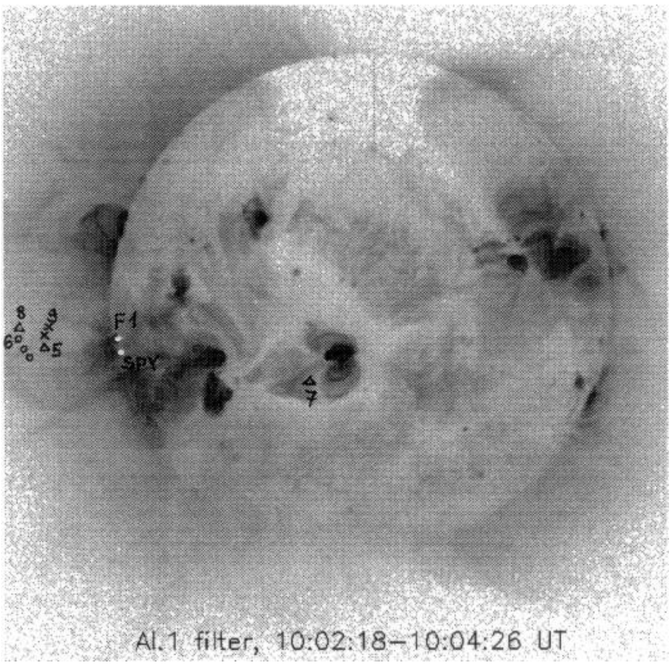

Figure 3b:

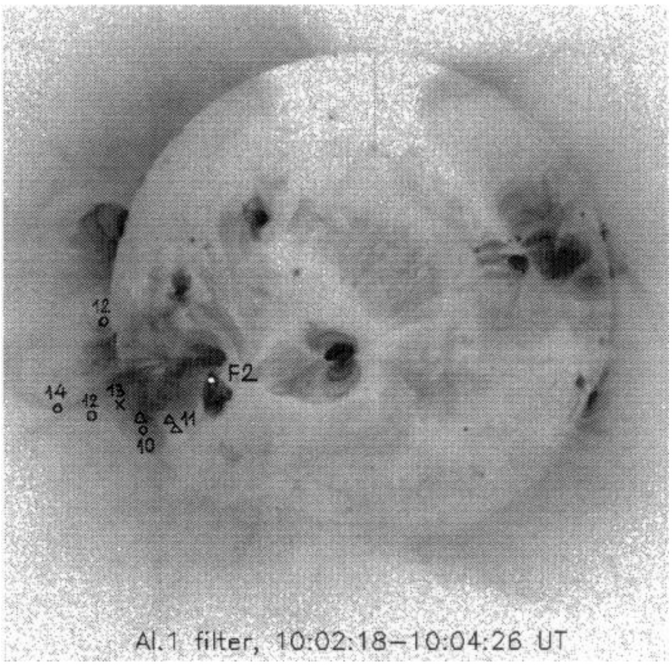

Figure 3c:

Figure 3: Composite picture of the Sun's soft X-ray made by YOHKOH SXT with A1.1 filter on the 5th of August 1992 for the period 10:02:18-10:04:26 UT. The spatial resolution is 4.9 arc sec. North is at the top, east - on the left. Heliographic positions of the radio burst sources, the flares and the spray are seen as projected on the picture and marked by following signs: for the radio burst sources at 164 MHz - o, at 236.6 MHz - δ, and at 327 MHz - x; for the flares and the spray - white dots. (a) Radio burst sources for the period 09:31:10 - 09:42:07 UT. (b) Radio burst sources and H_α events for the period 09:43 - 09:47:48 UT. (c) Radio burst sources and H_α flare for the period 10:08 - 10:11:25 UT.

spectrum as type IIIG with the strongest burst at 10:11:21 UT. In the meantime, at 10:11:17 UT, the radio burst at 164 MHz was recorded. Its source (12) was double and one of the components was situated in the vicinity of the AR I but the second component was placed between the AR I and AR II. Similarly, the radio sources: (13) at 10:11:20 UT at 327 MHz and (14) at 10:11:25 UT at 164 MHz were also recorded somewhere between the AR I and AR II.

Using the Solar Magnetic Field Synoptic Maps for Carrington rotations 1858 and 1859 (SGD 578-I, SGD 579-I) we concluded that the flares F1 and F2 had occurred in the channels of the polarity inversion (see Figure 1).

During the satellite day between 09:42 and 10:44 UT the SXT provided partial-frame images (PFI) of the AR 7242 located near the west solar limb. Nevertheless, full-frame images (FFI) taken by the SXT during the same time period allow to analyse the soft X–ray structure of the investigated active regions. The spatial resolution of each FFI was 4.9 arc sec. One FFI was taken every 2 minutes, on average. Two relatively thin filters: 1265 **r**A Al (Al.1) and composite comprising 2930 **r**A Al, 2070 **r**A Mg, 562 **r**A Mn and

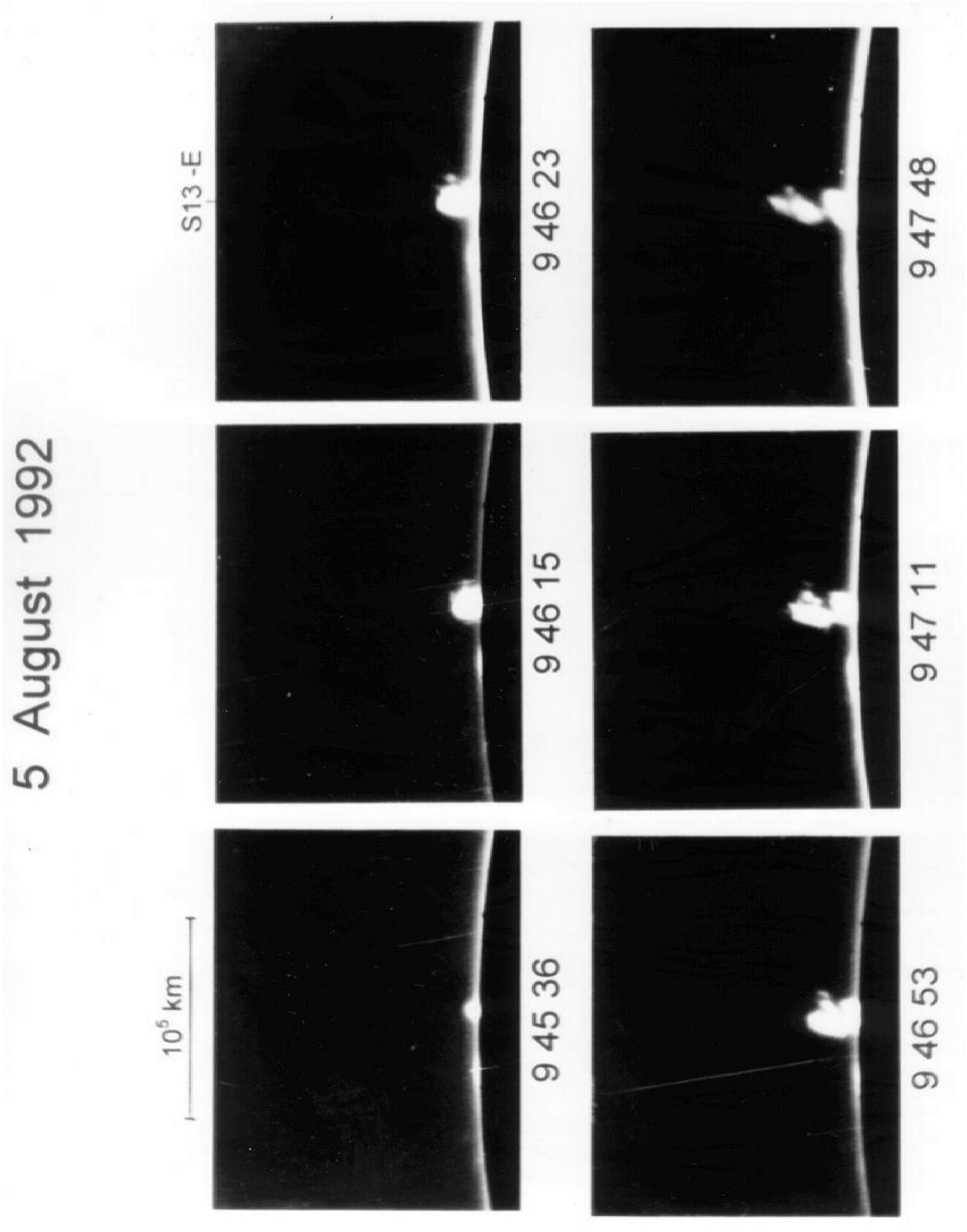

Figure 4: Development of the spray on the 5th of August 1992.

190 **r**A C (AlMg) have been used sequentially. They are sensitive to thermal radiation of several millions Kelvin plasma temperature. Two different exposure periods: 78 and 2668 ms were used for each filter. Short exposure pictures image the brighter part of active regions only, long exposure ones image weaker details of a soft X–ray structure but saturate brighter ones. Thus, only so-called *composite picture* "taking" the bright pixels from a short exposure FFI and the weak pixels from a long exposure FFI provides full

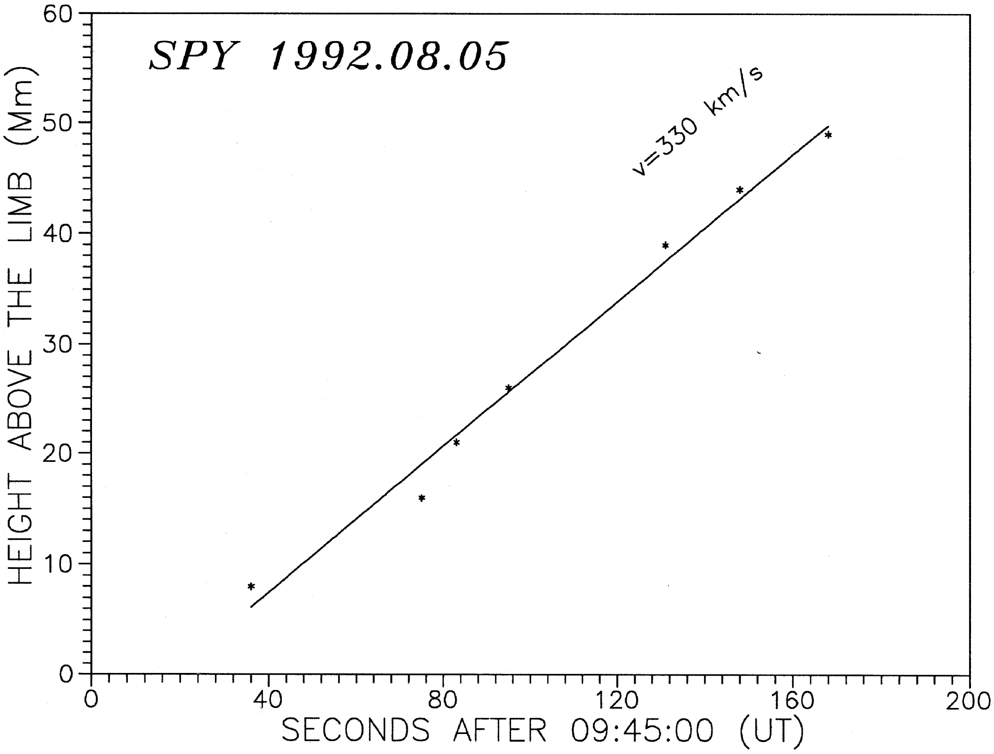

Figure 5: H-T diagram for the spray on the 5th of August 1992.

information about a whole soft X–ray Sun. This composite picture was used to compare the positions of the radio burst sources with X–ray loops.

4 CONCLUSION

We found in YOHKOH-SXT images the presence of the giant magnetic loops interconnecting investigated active regions. The existence of such loops can be also deduced from the radio bursts observed simultaneously above or nearby two remote active regions. The positions of these radio burst sources fit quite well with the X–ray loops.

The sequence of the interconnections can be devided into three different groups connected with the three periods of activity near the ARI and AR II.

The first manifestation of the interconnection between the AR I and AR II occurred just before the activation in H_α. It was the appearance of the radio bursts in sources (1) and (2) in AR II followed by the type III bursts in the sources (3) and (4) above the AR I (see Figure 3a). The movement down of the source (4) (marked on Figure 3a) is quite typical for a pre-flare activity.

The second manifestation of the interconnection in time of the F1 and the SPY was the appearance of the burst (7) near the AR II after the flare F1 and the spray SPY in the AR I (see Figure 3b). The bursts: (5), (6), (8) and (9), that had happened after the F1

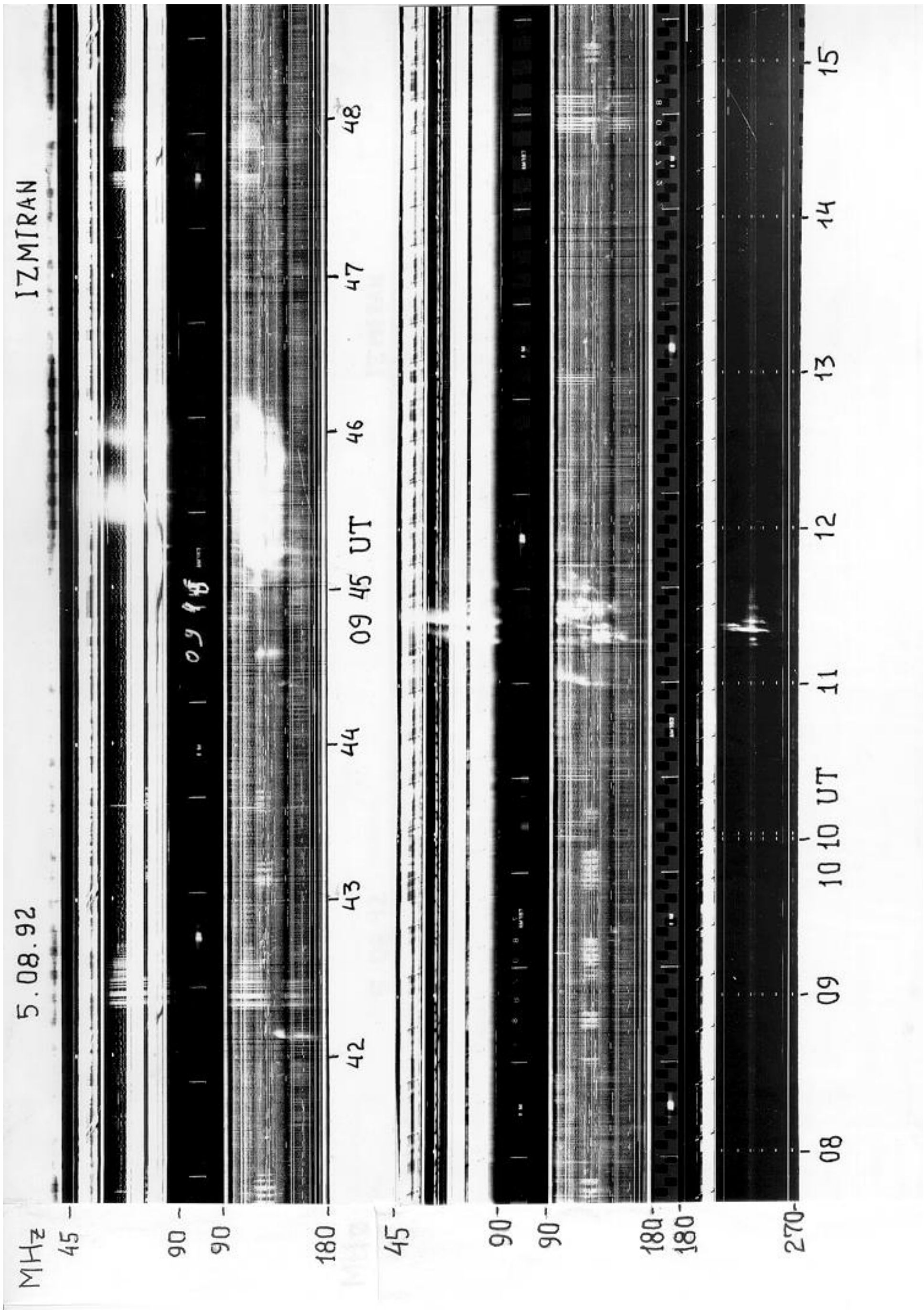

Figure 6: Dynamical radio spectra from IZMIRAN, Moscow, on the 5th of August 1992 (courtesy of Dr. Chernov).

above the AR I, were seen against a background of the X–ray loop with the plasmoid inside of it situated above the F1. The source of the type III+V radio burst (6) indicated some movement upwards. Because of the fact that type III burst of (6) was very short (see Figure 6), the movement concerned probably the type V burst of (6) only. This fact could be interpreted as an upward movement of the coronal plasma with magnetic field lines frozen in it. Besides, soon after (6), the ejection of plasma, SPY, from the same region was observed by us.

The third manifestation of the interconnection was the appearance of the type III burst in the source (12) above the AR I during the development of the F2 in the AR II. Additionally, the sources (13) and (14) of the type III radio bursts which occurred in time of the F2 are seen against a background of the large X–ray loop interconnecting the AR I and AR II (see Figure 3c).

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