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CORONAL INTERCONNECTION OF TWO ACTIVE REGIONS OBSERVED IN 3.5–5.5 keV X-RAYS

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ABSTRACT

Using HXIS data, we have studied further development of the coronal arch extending towards SE above the active region (AR) No.17255 in November 1980. The disappearance of that arch was followed by the appearance of another arch-like structure towards SW. We have studied the development of the new structure and classified it as an arch interconnecting AR 17255 with AR 17251, which was ~30° to the west. We estimate physical characteristics of this interconnection and compare them with Skylab data and the earlier arches.

INTRODUCTION

Švestka /1,2/ has studied the giant post-flare arch which appeared above the AR 17255 on 6 November 1980 when that region was on the eastern limb. He based his study on HXIS data from the bands 1 and 2 (i.e. energies 3.5 - 5.5 and 5.5 - 8.5 keV). From his conclusions we repeat here only three items which are important for our following study: a) the arch has been observed above the limb towards SE where no other AR existed, b) the arch revived twice during 25 hours after its formation - each time after a two-ribbon flare in the AR associated with radio types IV and II bursts, c) the arch cooled very slowly through radiation (conductive cooling was negligible) and its life-time was about 12 hours. Švestka's study ends after the second revival at noon on Nov 7 when the AR 17255 was still very close to the eastern limb. Originally, the aim of our study was to follow the development of the AR and possible revivals of the arch after Nov 7. But the observations show that after another (third) revival the arch ceased definitely to be visible in X-rays (3.5 - 5.5 keV) on Nov 10 and instead of it we could follow and study a new arch-like structure which appeared towards SW.

OBSERVATIONAL DATA

Figure 1 shows the relevant part of the photospheric situation on Nov 9 and the HXIS coarse field of view. We began to examine the data from Nov 7 at noon and around midnight we found the third revival of the SE arch, weaker than the previous one. It decayed for 12 hours before it became invisible. The third revival followed a flare which, in $H\alpha$ (Culgoora pictures), was almost a copy of the flare that caused the preceding second brightening. However, no radio type IV or II were reported in association with it.

On Nov 9 around 02:30 UT we have seen the birth of a new arch-like structure towards SW, which was already very pronounced at 04:30, as can be seen in Figure 2a. No obvious flare-association can be made for this brightening in AR 17255; however, at a distance of approximately 30° apart another AR (No.17251) was situated and just prior to the appearance of the new structure two big fla-

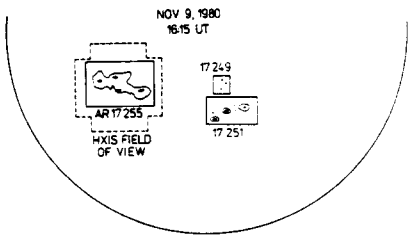

Fig. 1. Photospheric situation on Nov 9, 1980

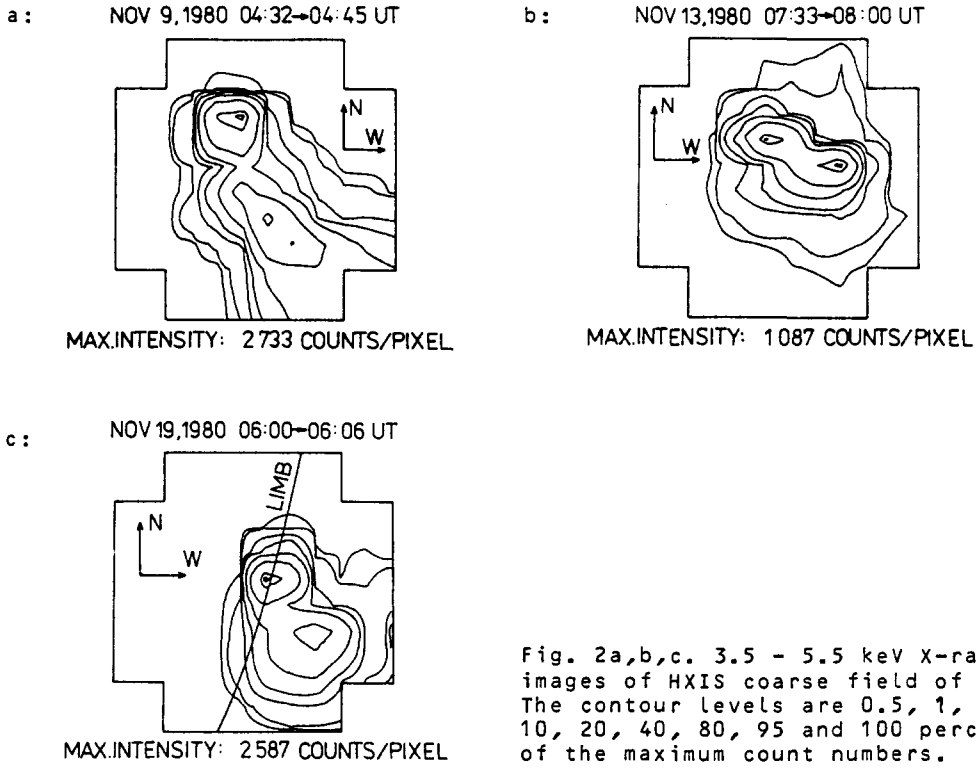

Fig. 2a,b,c. 3.5 - 5.5 keV X-ray images of HXIS coarse field of view. The contour levels are 0.5, 1, 5, 10, 20, 40, 80, 95 and 100 percent of the maximum count numbers.

res (1B,2B) were observed in that westward AR /3/. This fact, together with the actual shape and direction of the new structure, led to the conclusion that it was an interconnection of the two active regions visible in X-rays at energies between 3.5 and 8.5 keV. However, as the HXIS field of view was centered on AR 17255 during the whole period from Nov 6 to Nov 19 (with a gap from Nov 13 to Nov 17 when SMM was off), we have no observation to confirm definitely that the other part of the interconnection was really anchored in the other region.

The X-ray intensity of our interconnection (hereafter we will speak about interconnection to distinguish the new structure from the "Švestka-arch") fluctuated as can be seen in Figure 3. The intensity of the third revival of the SE arch is plotted in the same Figure 3 for comparison. In our case the intensity determination is often rather uncertain owing to the fact that we see a large part of the interconnection in projection on the AR and thus it is difficult to separate the emission of the interconnection from that of the active region. The HXIS field of view is clearly too narrow for a study of such extensive structures. To derive physical parameters we have read the intensities close to the border of the HXIS coarse field of view in the direction of the arch.

While the onset phase of the visibility of this structure seems to follow flares in AR 17251, the later brightenings are most likely associated with flares in AR 17255, if there was any flare-association at all. No two-ribbon flare was reported between Nov 8 and Nov 19 /3/. The life-time of revivals of the interconnection was much shorter (less than 6 hours) in comparison to the Švestka-arch. Intermittently the interconnection became invisible in X-rays as one can see in Figures 2b and 3. Because of technical problems aboard the SMM satellite we have no data between Nov 13 and Nov 17. On Nov 19 the AR 17255 was precisely on the western limb and after a flare in this region had occured we still could observe the interconnection in side projection (it was during the last day of pointed SMM operations) - see Figure 2c.

Our HXIS data resemble closely pictures of arches and interconnections of ARs seen in soft X-rays during the Skylab mission /4,5,6,7/. In /4/ and /7/ the authors derived the following physical parameters valid for interconnecting loops: temperature between 3 and 4 millions K, electron density less

than 2 x 10^9 cm^{-3}; the most frequent life-time was 6 - 7 hours.

PHYSICAL PARAMETERS FROM HXIS DATA

We have used the count ratio of energy bands 1 and 2 for deriving the temperature. The maximum value in the interconnection was found at 06:30 UT on Nov 11 equal to 14 x 10^6 K which is the same value as Švestka found in the SE arch on Nov 6. In most other revivals of the interconnection the maximum temperature was somewhat lower, within 9 - 12 x 10^6 K. As an example, the fall from the maximum value of 14 x 10^6 K to 8 x 10^6 K lasted about 70 minutes on Nov 11, from 06:30 to 07:40 UT, which, compared to "Švestka's" arches is relatively short (for example during the third revival of the SE arch on Nov 7 and 8 the temperature declined from 11 x 10^6 K to 7 x 10^6 K in six hours).

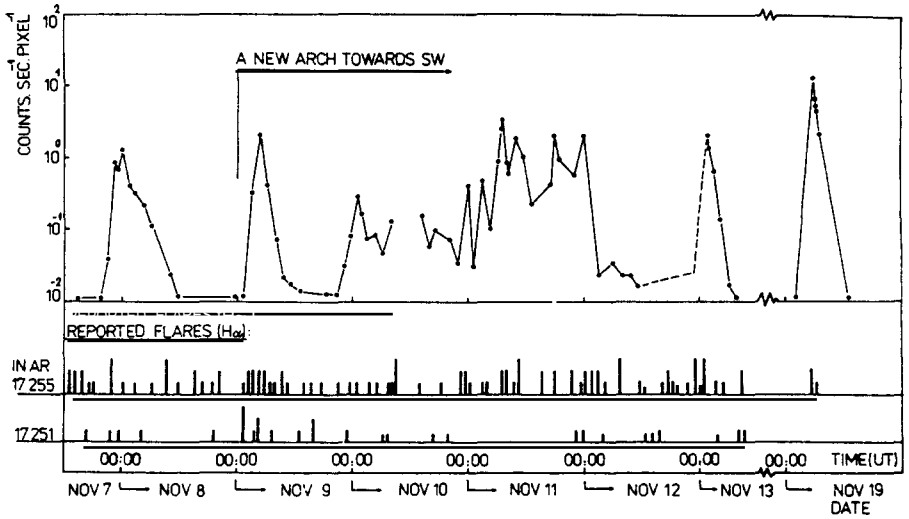

Fig. 3. Time variations of the brightness of the third revival of the coronal arch and of the interconnection (marked as "new arch"). Reported flares in H_α /3,8/ and their importances are approximately marked.

Based on the derived temperature and the measured intensity in band 1 we computed the emission measure. That enabled us to determine the electron density and the total energy in the interconnection (assuming a tube-like interconnection with a diameter of 100 000 km and a length of 300 000 km). Computing the electron density we supposed that the emitting plasma had dimensions corresponding to one coarse pixel in cross-section (23 000 x 23 000 km) times 120 000 km in the case of the side projection (on Nov 19) and, respectively, times 60 000 km when we saw the interconnection on the disc (for example on Nov 11).

Relevant results are presented in Table 1. In this table (and also in Figure 3) one can read that the most intense emission was observed during the revival on Nov 19 at around 05:30 UT. For this time we estimated the total energy equal to 7 x 10^{31} erg ($E = 3kn_eTV$, V being the volume of the interconnection).

CONCLUSIONS

(1) HXIS observed an interconnection of two active regions in 3.5 - 8.5 keV X-rays.

(2) This interconnection is a long-lasting one (we have observed it from Nov 9 till Nov 19) and its intensity may depend on flaring activity in the active regions.

(3) If so, then only some flares in the active region cause revivals of the interconnection. In contradistinction to the "Švestka-arch" these flares apparently need not to be two-ribbon flares.

(4) Derived temperature is in the range of 7 - 14 x 10^6 K; electron density

n_e = 2 - 8.5 x 10^9 cm^{-3}. These values are higher than the values derived from Skylab data.

(5) The radiative cooling time derived in the same way as in /1/-equation(3) is longer than the observed cooling time and this indicates that not only radiative but also conductive cooling took place in the interconnection. This is a significant difference from the earlier observed arches /1/ which cooled for more than 10 hours purely by radiation.

TABLE 1 Physical parameters of the interconnection derived from HXIS data

Date and Time	Position	Temperature (10^6 K)	Max. Intensity (*)	EM (cm^{-3})	n_e (cm^{-3})
Nov 11 06:04 UT		11	1.0	7.0 x 10^{46}	2.2 x 10^9
Nov 19 05:30 UT	centre	11	27.0	1.9 x 10^{48}	8.5 x 10^9
	border	7	1.67	0.8 x 10^{48}	5.7 x 10^9
Nov 19 06:00 UT	centre	9.5	7.2	0.8 x 10^{48}	5.7 x 10^9
	border	6	0.42	0.5 x 10^{48}	4.3 x 10^9

* = counts.sec^{-1}.$pixel^{-1}$

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