X-RAY JETS IN A REVERSED POLARITY REGION AND INTERPLANETARY EFFECTS

B. Schmieder\textsuperscript{1,2}, L. van Driel\textsuperscript{1,3}, N. Mein\textsuperscript{1}, P. Mein\textsuperscript{1}, R. Willson\textsuperscript{1} and A. Raoul\textsuperscript{1}

\textsuperscript{1} Observatoire de Paris, Section de Meudon, F-92195 Meudon Principal Cedex, France
\textsuperscript{2} ITA, P.O.Box 1029, Blindern, N0315 Oslo, Norway
\textsuperscript{3} Konkoly Observatory, H-1525 Budapest, Pf. 67, Hungary
\textsuperscript{4} Department of Physics and Astronomy, Tufts University, Medford, MA 02155 USA

\section*{ABSTRACT}

We follow the evolution and activity of the AR 7912 between 12-20 October 1995 by using multiwavelengths observations: white light photoheliograms of Dobrecen, chromospheric intensity and velocity field images of the Multi Channel Subtractive Double pass spectograph (MSDP mounted on the German VTT on Tenerife), magnetograms of Kitt Peak, corona observations of the Yohkoh/SXT, the VLA and the Nançy radiopheliograph. We find that in spite of the high shear and flux emergence leading to mixed polarity regions, the flares in the group did not exceed the M-class level. On the other hand, the presence of high shear and minor fast-moving parasitic polarities was sufficient to produce eruptive events like X-ray jets (October 19 around 10:30 UT and 17:00 UT) and important coronal and interplanetary effects. A magnetic cloud was observed between October 18-20 approaching towards the Earth.

\textbf{Key words:} jets, Type III bursts, magnetic cloud

\section{1. Introduction}

Ejections of cool material (surge) have been frequently observed in H\alpha and transition zone lines in complex magnetic regions with mixed polarities (Schmieder et al. 1983). These latter authors have shown co-alignment of blue and red shifts along the surge axis suggesting twisting motions. It has been confirmed recently by Canfield et al. 1996. They are often accompanied by ejections of hot material called jets discovered by Yohkoh/SXT (Shibata et al. 1992) and Type III bursts (Chiuder et al. 1986).

The process of magnetic reconnection in the solar atmosphere can lead to the acceleration of particles in a thin current sheet separating regions of opposite magnetic polarity; these energetic particles may escape from the reconnection site and produce characteristic signatures at different heights in the active region. If magnetic reconnection occurs at the base of a large, relatively open structure in the chromosphere, cool plasma may be squeezed by untwisting magnetic fields and forced into the corona producing an H\alpha surge or ejection event. With a good survey of the solar phenomena during multiwavelength campaigns we present flares, jets and radio emission occurring in an active region during its disk passage and relate them to interplanetary events.

\begin{itemize}
\item 2. Observations
\end{itemize}

The AR 7912 during its disc passage was followed by different instruments. It is a region with reversed polarity group with vortex-like H\alpha fibril and X-ray loops pattern. A series of flares were observed mainly between the 12-16 October 1995. The jets appeared over a mixed magnetic polarity region in the vicinity of the leading spot.

\subsection{2.1. Magnetic Evolution of AR 7912}

The AR consisted of a round leading and smaller dispersed trailing spots with a few parasitic polarities disturbing the bipolar structure. The magnetic evolution of NOAA AR 7912 between Oct 12-20, 1995 is displayed in Fig 1. Between October 12 to 16, this South hemispheric AR had reversed polarity. In the following, positive polarity part of the AR two bipoles emerged: bipoles 9 - 11 and 3 - 5; the former has reversed, the latter normal polarity with a high inclination. This emergence was responsible for the series of flares. The negative polarity spots of the diverging new bipoles gradually cancelled with the positive polarity magnetic environment by 17 October. During 16 October another mixed polarity area developed to the South-East of the leading spot. The latter area produced the jet events on Oct. 19 (Fig. 2).

Sunspot proper motions were interesting as well, with the leading spot moving along a loop and some following spots moving westward instead of their usual eastward direction. The latter was mainly due to the appearance of reversed and highly inclined bipoles in the trailing region of the AR (van Driel et al. 1998).


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Figure 1. AR 7912 between October 12 - 20 1995 (Kitt Peak magnetograms)

Figure 2. Yohkoh/SXT full disk image and the location of Nançay Type III bursts. The western Type III bursts (square and dot) occur at 10:25 UT, the eastern ones (square and dot) at 10:28:40 UT are well associated spatially and temporally with the eastern X-ray jet branch, the emission at 327 MHz (triangle) at 10:28:40 UT looks more associated with the AR.
2.2. Hα observations

Hα observations were obtained with the MSDP instrument at the German VTT (Tenerife). Along the magnetic inversion line on the eastern side of the big spot a filament was observed, which underwent strong changes during and after the 1B/B3.2 flare and jet which started at 10:24 UT. The jet, well observed in the corona, unfortunately was out of the field of view of the MSDP instrument which was temporary reduced to the vicinity of the spot. Also, the observing time with the MSDP ended before the afternoon jet, thus we do not know whether the hot jets were accompanied by surges, (e.g., ejection of cool material) or not.

The MSDP images taken at 10:58:30 UT (Fig. 3) show the structure of the active region after the flare (the flare ended at 10:43 UT). In the MSDP observations we see two regions of interest, one is a long absorbing feature, the filament. In the far wings of Hα line (± 0.9 Å) the filament is still visible. It indicates large Doppler-shifts, red and blue shifts nearly cospatial which correspond to the existence of a large twist along the filament. This filament motion reflects the large vortex pattern existing in the AR. In the north-west of the preceding spot some upflows are observed co-spatially with a later VLA source (at 6.2 cm, Fig. 6).

2.3. X-ray emission

The region was quite flare-active but it did not produce very important flares: there was no X-flare, but three M-flares and dozens of smaller flares originated from the region.

AR 7912 showed a vortex-like appearance soft X-rays (Fig. 4), indicating the presence of strong currents. The X-ray loops have a sigmoid shape with a positive helicity corresponding to the global south-hemisphere helicity.

Furthermore, two spectacular jets were observed with Yohkoh SXT, the Nançay radio heliograph and with the VLA on Oct. 19, what we analyse in detail, since due to the observing campaign we have a good data coverage of these events (Fig. 2).

2.4. Jets

The first jet at around 10:30 UT, close to its footpoint, reached about three times higher emission measure than the second one at around 17:00 UT, while the main body of the jets were not very different neither in emission measure nor in temperature (Fig. 5). For the electron densities of the jet along the jet body, assuming a diameter of 7000 km we got $N_e \sim 4 \times 10^9$ cm$^{-3}$. The jets extended with a speed at least 700 kms$^{-1}$ and reached the length of 2.5-3 $\times 10^5$ km. The second jet was preceded by a loop.
Figure 4. Yohkoh/SXT soft X-ray images of AR 7912 between October 12-20 1995

Figure 5. Yohkoh/SXT soft X-ray images on October 19 1995: showing the basis of the two jets in AR 7912 (notice the increase of brightness at 10:29:47 and at 17:01:45 UT)
brightening starting at N-NE to the big preceding spot, a few minutes before the jet onset, which corresponds to the radio source observed with the VLA source at 6.2 cm low in the corona (Fig. 6).

2.5. Radio-bursts

The first event was also observed with the Nançay radio heliograph at 167, 236 and 327 MHz. Type III activity, indicating the presence of electron beams, superimposed on a noise-storm was clearly visible. Type III bursts first appeared at 10:25 UT, coincidentally with the onset of the X-ray jet, at 164 MHz and 236 MHz close to the storm position and in the direction of the X-ray jet. At 10:28:40 UT a new group of sources appeared eastward of the former activity, which may correspond to another jet branch along the more eastern path seen in the Yohkoh images (Fig. 2).

The second X-ray jet event was also observed with the Very Large Array (VLA) at 6.2, 20.7 and 91.6 cm. For this event, VLA snapshot maps at 6.2 and 20.7 cm reveal low-brightness temperature changes in source structure at the site of the X-ray jet during the pre-burst, impulsive and decay phases. The source at 6.2 cm is at the place where upflows were observed in Hα before the first jet. The source at 20.7 cm covers the location of the jets. The VLA 91.6 cm observations also show noise storm emission above the active region but there is no clear temporal correlation between this later X-ray jet and the impulsive decimetric bursts that were observed during this period. Because the VLA observations began during the decay phase of the X-ray jet, we cannot say that Type III bursts were not produced during its early stages, although during the time interval covered by this event there was no Type III, but there was a Type V emission reported in the Solar-Geophysical Data. The Type V emission was observed in the 30-80 MHz range indicating that electron beams have been accelerated during the event.

2.6. Interplanetary Events

The solar wind density, velocity and interplanetary magnetic field are data obtained from the WIND spacecraft respectively with the Solar Wind Experiment and by the Magnetic Field Instrument. They detected magnetic clouds as they pass the Earth: magnetic field increases during the period of 18-20 October. The magnetic field in the cloud is twisted and the density of the solar wind changes. Compared with the flare and jet times, and the delay of 78 hours in average to travel from the Sun to the Earth, it seems more probable that the magnetic clouds originated from ejections during the first series of flares between 14 and 16 October 1995 than initiated by the jets (Fig. 7).

3. Conclusion

The two X-ray jets observed on Oct. 19, 1995 originated from a reversed-polarity AR over a mixed polarity region close to the leading spot. At least one of the jets had a multiple structure (two jet-paths) indicating the complexity of the magnetic topology.

Although the X-ray observations show that the two jets had similar temperatures, emission measures, speeds and trajectories they appear to have had dis-
similar metric responses to these events (several different signatures of particle acceleration during the times of these two jets). First, the VLA observations at 6.2 cm show the appearance of a new microwave source at the base of a bright X-ray loop connecting the footpoint of the second jet and the main sunspot about 5 minutes before the start of the impulsive phase. This new source could, in principle, be due to an increase in the temperature, density or magnetic field strength in this region, or a combination of these. Analysis of the Yohkoh data shows indeed an increase in the electron temperature and emission measure of a loop with a footpoint under the radio source during these times. Furthermore, a change in the magnetic field topology might have been produced during the magnetic reconnection event that subsequently led to the ejection of the X-ray-emitting jet plasma.

Type III bursts were observed in Nançay for the first jet and Type V were reported for the second jet. Both type III and type V bursts indicate the presence of propagating electron beams in the corona. We realise that the two jets which had similar characteristics, produced radio response in different wavelength ranges in the corona.

Looking at the time table of the magnetic clouds it appears that it would be better to relate them to the flares between the 14-16 October than to the jets on the 19 October.

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