ENERGETIC ELECTRONS AND MAGNETIC FIELD STRUCTURES IN THE CORONA

M. Pick [1], A. Raoult [1], G. Trottet [1], N. Vilmer [1], K. Strong [2], A. Magalhaes [3]

[1] *DASOP, Observatoire de Meudon, Meudon 92195, France*
[2] *Lockeed Palo Alto Research Laborarory, Dept. 91-30, 3251 Hanover St., Palo Alto CA 94304, U.S.A.*
[3] *Observatorio Astronomico, Universidade do Porto, Monte da Virgem, 4400 vila Nova De Gaia, Portugal*

Abstract

The Nancay Radioheliograph provides imaging observations of the low and middle corona. Such observations combined with X-ray and gamma ray observations constitute an unique way to get informations on the the coronal structures in which electrons propagate. This is illustrated on two examples: 1) the first joint observation of a coronal structure between the soft X-ray telescope aboard the Yohkoh satellite and the Nancay multifrequency radioheliograph; a radioburst was used as a tracer of a coronal structure and its spectral identification was obtained with the radiospectrograph of the University of Porto 2) the magnetic structures involved in the flare acceleration processes.

1. Introduction

Energetic beams of particles are accelerated during solar flares. The observable signatures are revealed in the hard X-ray, gamma-ray, radio and optical domains. In particular, type III radiobursts represent the most direct evidence for electron beam propagation in the corona. Radio imaging observations, in coordination with X-ray observations have been used intensively as tracers of coronal magnetic structures in which energetic electrons propagate from acceleration sites. From these investigations, important conclusions have emerged and can be summarized as follows:

- Successive different structures are involved in the flare development, even during the initial phase. The growing efficiency of particle production is directly related to the increasing number of magnetic structures involved during the flare development (Raoult *et al.* 1985,

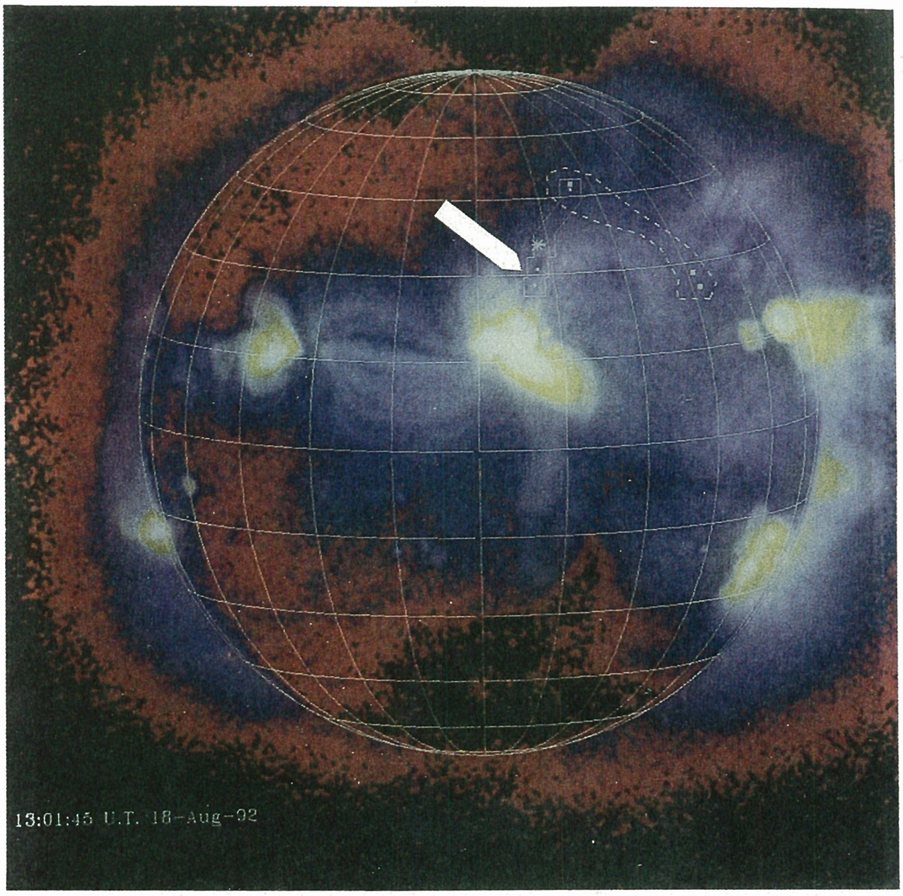

Fig. 1. Soft X-ray image. The centroid positions (points) of the type III/U burst observed at 5 frequencies have been superposed. Full line: shape of the ascending branch. Dashed line: shape of the descending branch.

Trottet *et al.* 1993). These results support the concept of fragmentation of energy release during flares (Vlahos 1993).

- The beam propagation depends on the physical conditions of the ambient medium. The corona is highly structured and the electron beams have been found to propagate along widely diverging discrete coronal magnetic tubes rooted inside the accelerating site (Trottet *et al.* 1982, Pick and Van den Oord 1990).

The Nancay multifrequency radioheliograph is operating at five frequencies in the 150-450 MHz band (The Radioheliograph group 1993). This paper shows the performance of this instrument in probing the corona within approximatively the altitude range of 0.1-0.6 solar radius. This is illustrated by correlative studies between X-ray and radio observations.

2. Observation of a coronal structure

On august 18, 1992, a type III burst was observed from 700 to 200 MHz at 13:00:45 UT by the radiospectrograph of the University of Porto in Portugal. This type III burst was followed 5 seconds later by two "descending" branches drifting from low frequencies toward high frequencies and thus can be designed as a type III/U burst. The first descending branch was hardly detected by the spectrograph, due to its sensitivity threshold, but was well seen with the Nancay multifrequency radioheliograph. Figure 1. shows the image obtained with the Soft X- ray telescope at 13:01:45 UT. The photography presented here has been overexposed for the present purpose. On the same image, the centroid positions (points on the figure) of the radio burst observed at 5 frequencies, 435, 408, 327, 236, and 169 MHz, have been superposed. The full line represents the shape of the ascending type III branch derived from the source locations and sizes measured at each frequency. The dashed line corresponds to the descending branch. (The second descending branch only seen in a narrow frequency range will not be discussed here; the star symbol reported in the figure corresponds to its location at 435 Mhz). The ascending branch has the classical behaviour of a type III burst with the lowest frequencies corresponding to locations far from the active center. At 236 and 164 Mhz, the emission is near the turnover frequency and the sources are broad and complex; there is an overlapping between the ascending and descending branches. The descending branch presents an elongated eastward shape with the locations at high frequencies found at the extremity of this branch. The shape of the coronal structure inferred from these radio observations fits a coronal arch that effectively overlays an X-ray arch. This joint observation clearly illustrates that radio imaging observations are accurate tracers of coronal structures.

3. Particle acceleration and magnetic structures

Previous studies have shown that radio and hard-X ray emissions are produced by electrons injected into small and large scale magnetic structures from the same acceleration site. Radioheliograph observations revealed that at the onset of the impulsive phase, characterized by a rapid increase of the hard X-ray emission, a new radio source at distinct location from the preceding ones, visible during the preimpulsive phase, appears systematically. These observations were interpreted as an evidence of a new magnetic structure involved in the flare energy release (Raoult *et al.* 1985). This was more recently extended to flares where >10 Mev emission is produced; the onset of this emission was also found to coincide with the appearance of a new involved magnetic structure (Trottet *et al.* 1993; Chupp *et al.* 1993). All these results suggest that the energetic electron spectrum is directly related to the evolving morphology of the active region magnetic field structure. This is illustrated in Figure 2.. This figure shows the time history of the june 3, 1982 event at 169 MHz, and at several microwave frequencies and for the hard X-rays and Gamma-rays. The comparison clearly shows a close time correlation of all the emissions during the initial phase of the event. The successive X-ray or gamma-ray peaks are associated with the appearance of new 169 MHz sources. These sources are reported in the right side of the figure: The event at 169 MHz exhibits five successive parts which come from different coronal locations. The detailed study will be reported in Trottet *et al.* 1994. The detailed comparison of the time history for microwave and metric emissions, X-ray and gamma-ray have been now achieved only for a few cases with energies greater than 1 MeV. These cases are listed below with the corresponding references. The X-ray and gamma-ray observations were obtained with the gamma-ray telescope aboard SMM (Forrest *et al.* 1980) and with the PHEBUS instrument aboard the GRANAT satellite (Barat *et al.* 1988). No imaging hard X-ray observation was available.

June 3, 1992 : Nuclear line excess (Trottet *et al.* 1994).

September 9, 1989: Nuclear line excess, Emission at energies >10 MeV (Chupp *et al.* 1992).

May 15, 1990: Emission at energies < 1.3 MeV (Trottet *et al.* 1993).

June 11, 1990: Emission at energies >10 MeV (Trottet *et al.* 1993).

4. Conclusion

In view of these results, joint soft and hard X-ray Yohkoh observations and Nancay radioheliograph observations offer a new potential opportunity to investigate in details the

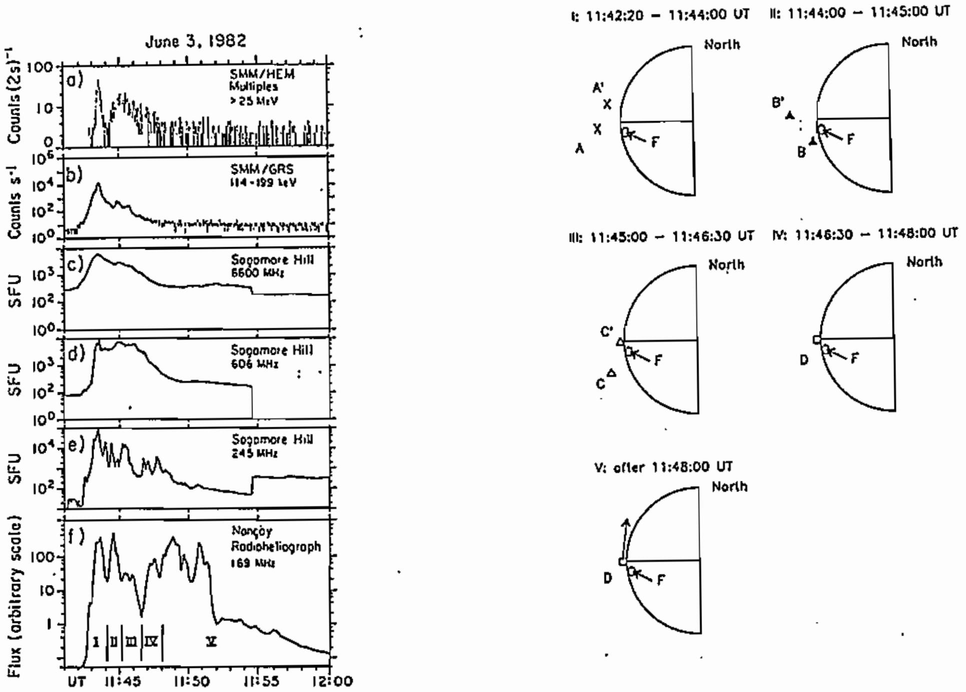

Fig. 2. Left side: time histories are shown for hard X-ray, gamma ray and several radio discrete frequencies. Time intervals when new sources are observed at 169 Mhz are indicated by Roman numerals. Right side: Positions of radio sources observed for successive time intervals.

magnetic structure of the flaring region involved in the flare acceleration process, and particle propagation in the corona.

References

1. Chupp E.L., Trottet G., Marschhauser H., Pick M., Soru-Escaut I., Rieger E., Dunphy P.P., 1993, *Astron. Astrophys.*, **275**, 602.
2. Barat C. et al.,, 1988 *in Nuclear spectroscopy of astrophysical sources, eds G.H. Share and Gehrels, A.I.P., New York*, **170**, 395.
3. Forrest D.J., Chupp E.L., Ryan J. M. *et al.*, 1980, *Solar Physics* , **65**, 15.
4. Pick M. and Van Den Oord, 1990, *Solar Physics.*, **130**, 83.
5. Raoult, A.Pick, M., Dennis, B.R., Kane, S.R., 1985, *Apj*, **299**, 1027.
6. The Radioheliograph group, 1993, *Adv. Space Res.*, **13**, 9, 411.
7. Trottet G., Pick M., House, L., Illing R., Sawyer C., Wagner W., 1982, *Astron. Astrophys.*, **111**, 306.
8. Trottet G., Vilmer N., Barat C., Dezalay J.P., Talon R., Sunyaev R., Terekhov O. and Kunznetsov A., 1993, *Adv. Space Res.*, **13**, 9, 285.
9. Trottet G., Chupp E.L., Marschhauser, H., Pick M., Soru-Escaut, I., Rieger E., Dunphy P.P., 1994, *Astron. Astrophys.*, in press.
10. Vlahos, 1993, *Adv. Space Res.*, **13**, 9, 161.