RADIO SIGNATURES OF MAGNETIC RESTRUCTURING DURING THE 2000 JULY 14 MAJOR SOLAR EVENT

C. Caroubalos[(1)], P. Tsitsipis[(4)], A. Kontogeorgos[(4)], X. Moussas[(2)], C. E. Alissandrakis[(3)], A. Hillaris[(2)], P. Preka-Papadema[(2)], J. Polygiannakis[(2)], J.-L. Bougeret[(5)], G. Dumas[(5)], V. Kurt[(6)], C. Vassiliou[(2)], C. Perche[(5)], K. Gazeas [(2)], G. Kolovos[(2)]

[(1)]Department of Informatics, University of Athens, GR-15783 Panepistimiopolis Zographos, Athens, Greece
[(2)] Section of Astrophysics, Astronomy and Mechanics, Department of Physics, University of Athens, GR-15784 Panepistimiopolis Zographos, Athens, Greece, e-mail xmoussas@cc.uoa.gr
[(3)] Section of Astro-Geophysics, Department of Physics, University of Ioannina, GR-45110 Ioannina, Greece
[(4)] Department of Electronics, Technological Education Institute of Lamia, Lamia, Greece
[(5)] Observatoire de Paris, LESIA, CNRS UA 264, F-92195 Meudon, Cedex, France
[(6)] Institute of Nuclear Physics, Moscow State University, Moscow 119899, Vorobievy, Gory, Moscow, Russia

ABSTRACT/RESUME

We analyse the fine structure of the type IV radio burst, during the main phase of the 14th July 2000 major event recorded by the radiospectrograph *ARTEMIS-IV*, in the 110-650 MHz (10Hz sampling rate) and the 270-450 MHz (100Hz rate) range. In this report we focus on variations in frequency drift rate and repetition rate of *fibers bursts*. A pronounced asymmetry between the number of bursts with positive and negative frequency drift is noted at certain time periods. These variations follow closely the evolution of the magnetic structure associated with the major solar event and the onset of the corresponding CME.

1. OBSERVATIONS

On the 14th July 2000 a major event took place in AR 9077 [2-10, 20]. The SXR flare (GOES Class X5.3) started at 10:03 UT reaching a peak at 10:24 UT. A Type II burst started almost simultaneously with the flare peak followed by type IV continuum, recorded by *ARTEMIS IV* radiospectrograph [5], located at Thermopylae, Greece [1]. The rich fine structure of the type IV event included fiber burts and pulsations (fig. 1).

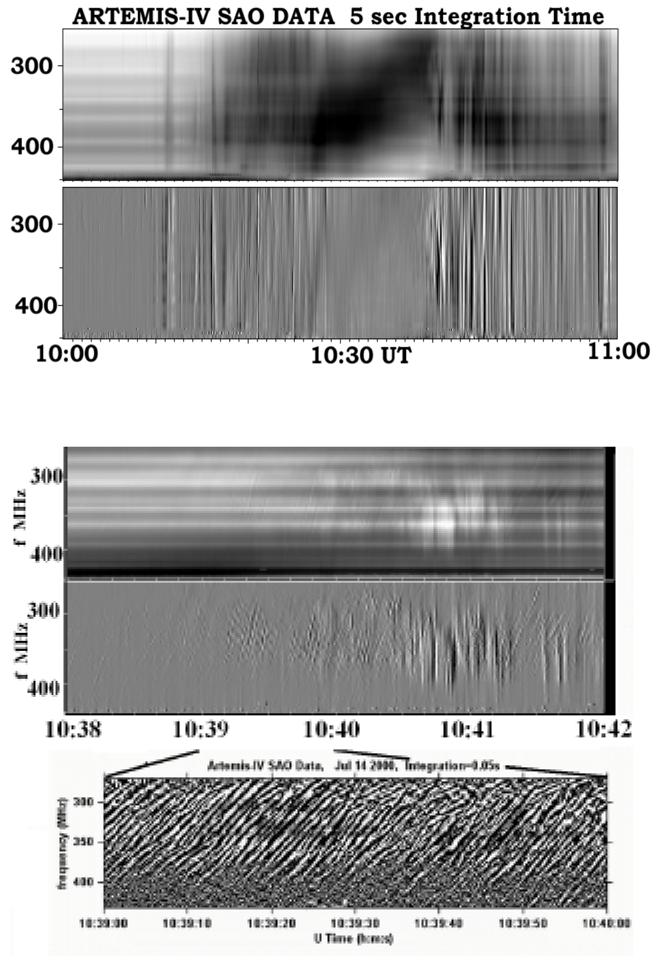

Fig 1 SAO dynamic spectra (Intensity & time derivative) of the 2001 July 14 event (integration time 5 sec) . Upper panel: main phase of the event, middle panel: 4 minutes of data (integration time 0.25 s), bottom panel: Fine structure (*fibers bursts*, integration time 0.05 sec).

2. DATA ANALYSIS AND RESULTS

The radio data recorded by *ARTEMIS IV* Acoustooptic Spectrum Analyser (SAO), with 1/100 sec time resolution, were subjected to high pass FIR filtering. This rejected local interference and the low frequency part of the signal enhancing thus pulsations and fibers. Applying a high pass FIR filter to the frequency, we separated these two components of the fine structure. The second filter suppressed the gain variation along the frequency axis, thus emphasising the medium drift bursts (fiber bursts). The resulting dynamic spectrum after the double filtering process is shown in fig 1, bottom panel.

Fourier analysis of the intensity of the radio emission in various frequencies shows quasi-periodic behaviour of about 0.5 to 2 sec during the type IV pulsations.

We trace each fiber and the estimate frequency drift rate (*df/dt*). We can assume that beams of electrons produce the fibers; the beams have different characteristic velocities and follow magnetic lines at various angles to the radial direction. Moreover the exciter velocity from the frequency drift (*df/dt*) is estimated, assuming a *Newkirk* coronal density model [16, 17]. The distributions of negative and positive frequency drift rates for every minute have been obtained (fig. 2). The velocity distributions have also been calculated for every minute. The velocity distribution, both for beams going away and returning back to the Sun during all the time period of the event are shown in fig 3. Comparison of the velocities of the two beam populations shows that electrons with higher velocities are the ones that do not return back to the Sun, as expected.

The number of fiber bursts per minute is also calculated for all the time period of the event, both for negative and positive frequency drifts, outbound and inbound beams respectively. These rates and their ratio are shown in fig 4. The rate of outbound beams is at times significantly larger than the rate of inbound beams. Their ratio indicates large deviations from unity and it probably marks time periods where many of the magnetic field lines are open. The average velocities of electron beams vary between 2000 to 10000 km/sec for all the time period as shown in fig 4 (lower panel). More outbound beams appear after 10:26 UT when as the flare spreads eastward on SOHO/EIT, TRACE and NRH [5,20,21].

The evolution of beams (fig 4) shows that the number of beams leaving the Sun is much larger than the number of those going down during the beginning of the onset of the main flare and the type II burst (fig 4 middle panel). The ratio of beams becomes maximum in the middle of the type IV burst (10:37 UT), which started at about 10:27 UT (maximum of soft X-rays, GOES) and lasted till 10:43 UT. The largest deviation of ratio from unity coincides with the time of hard X-ray secondary maximum [5] and the CME onset and development. The average beam velocity estimated for every minute follows roughly the soft X-ray intensity and the estimated injection function (fig 5). The velocity of the beams shows a first maximum with the onset of type II burst and the onset of the flare, another maximum coincides with the maximum of soft X-rays and the maximum of the flare. The average beam velocity becomes very small few minutes after the type II (and the maximum of ratio) and after the middle of type IV, just after the maximum of the ratio. Conclusively the velocities are large during the beginning of type II and type IV, at the maximum of

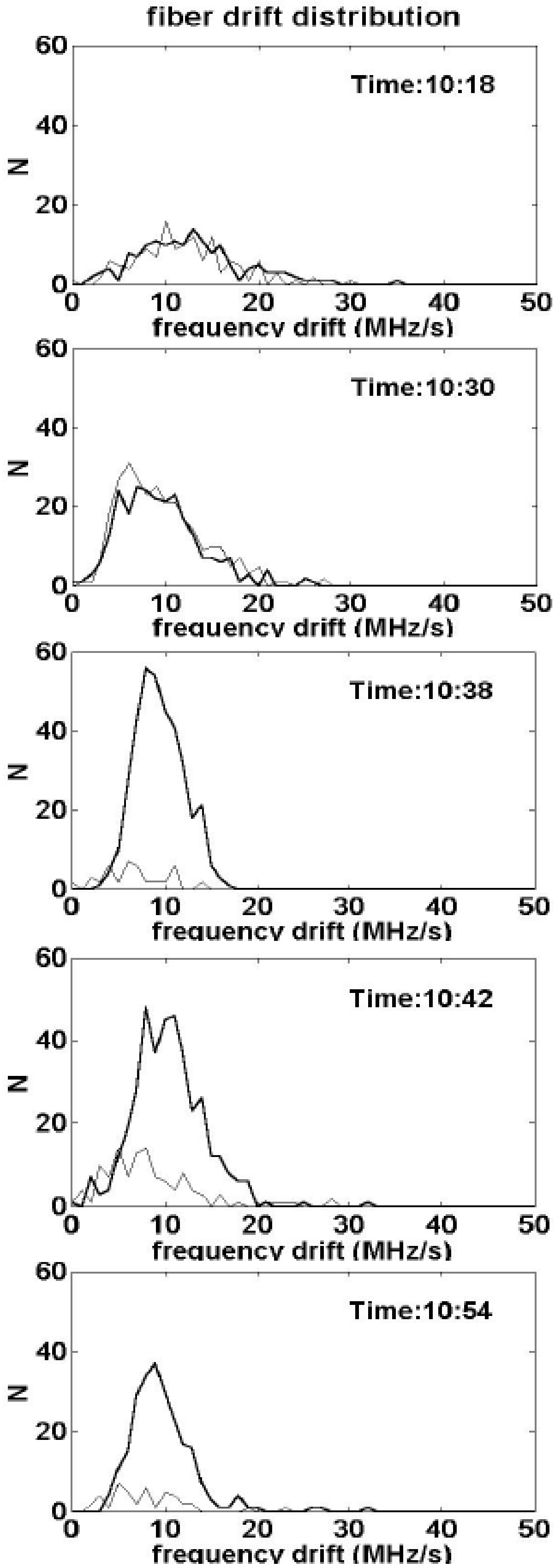

Fig. 2: Distributions of fibers in Frequency Drift Rate.
Thick lines: negative *df/dt* (outbound beams)
Thin lines: positive *df/dt* (inbound beams)

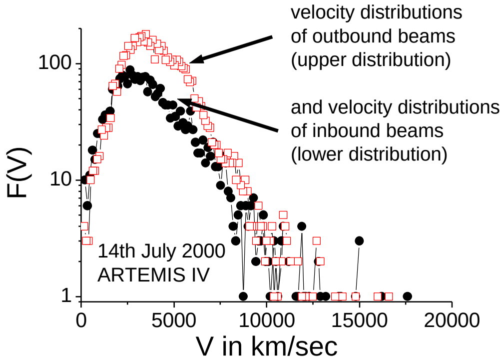

Fig 3 Average distribution of electron velocities for outbound and inbound beams during the time period of the event of 14th July 2000.

H-alpha and soft X-rays and the beams become slower when more beams leave the Sun. This probably indicates that the beams are accelerated more when they are trapped in closed field lines.

A secondary maximum of the ratio occurs when 1.2 GHz flux increases [10]. Many more variations of the ratio take place later, following flare activity till 14:00 UT.

From soft X-ray data (GOES, fig 5 upper panel) we have calculated the energy injection function and the temperature of the region using well-established methodology [18, 19]. The temperature varies from $6\cdot10^6$ to a maximum of $20\cdot10^6$ and then decays gradually, while the injection function has three peaks as shown in fig 5 (lower panel). The temperature and the injection function follow the time variations of the average velocities of the beams (fig 4 lower panel, 10:18, 10:33 UT).

3. CONCLUSIONS

The type IV pulsations show quasi-periodic behaviour with periods 0.5 to 2 sec

A statistical analysis of occurrence rate and frequency drift for every minute of observations shows:

1. Time varying occurrence rate of fibers bursts (fig 4, upper panel).
2. Time varying average frequency drift, which apparently corresponds to variable exciter velocity (fig 4, lower panel).
3. Drastic variations of the ratio of occurrence rate of fibers bursts with positive frequency drift to fibers with negative frequency drift (fig 4, middle panel). These are, presumably, associated with changes of the magnetic topology of flaring region, or coronal mass ejection, and/or energy release (H-alpha, GOES/SXR, TRACE, SOHO [2-10]).

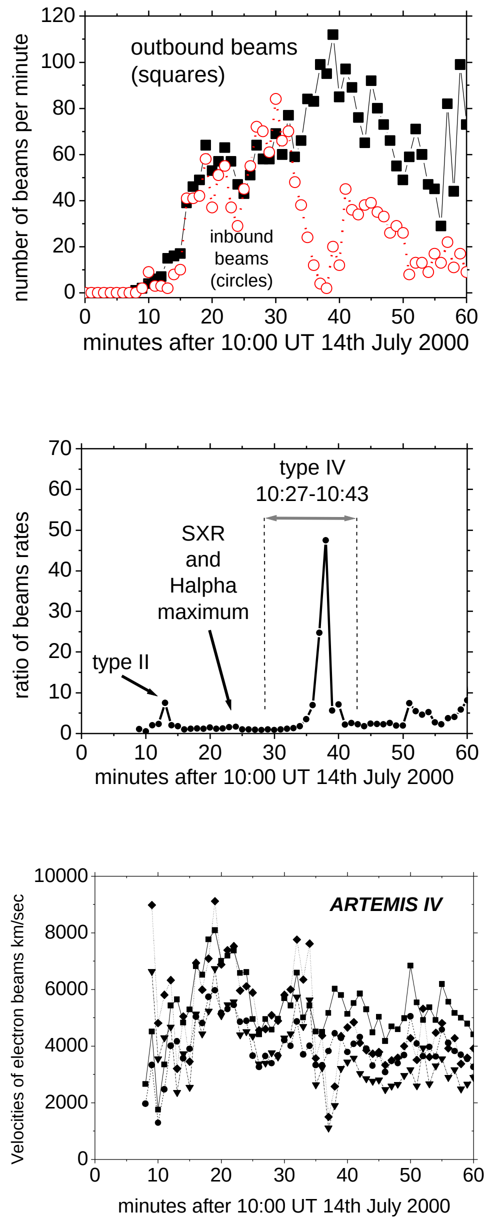

Fig.4: Upper panel: Ratio of positive to negative drift rates vs time.
Middle panel: number of fibers with positive and negative frequency drift rate as a function of time.
Lower panel: mean velocities of electrons of the beams.

We propose that when the ratio of beams away from the Sun to beams towards the Sun becomes much larger that unity, magnetic line opening (or reconnection?) occurs and/or the observed CME onset is in progress.

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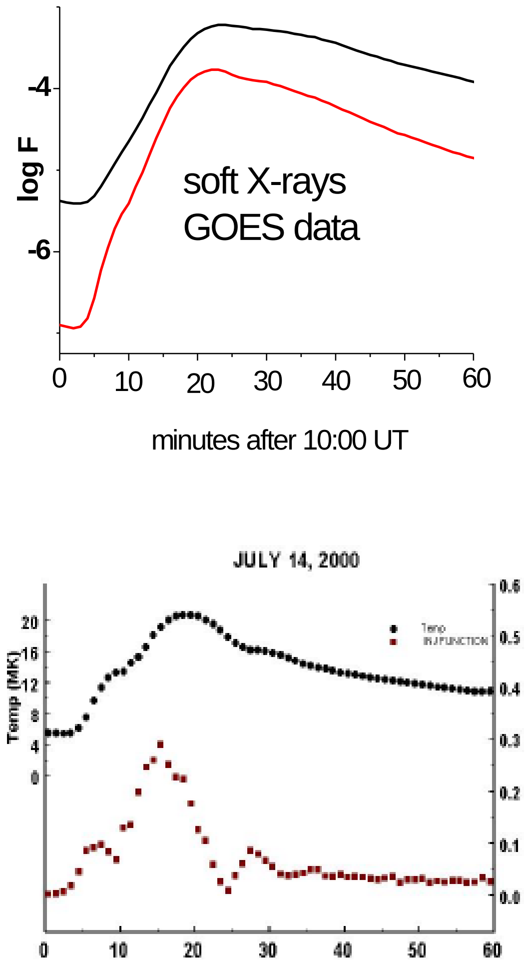

Fig.5: upper panel: SXR from GOES,
Lower panel: Temperature and injection function of the SXR Flare vs time (minutes after 10:00 UT, 14th July 200)

4. REFERENCES

1 Caroubalos, C.; *et al*, The New Multichannel Radiospectrograph ARTEMIS-IV/HECATE, of the University of Athens *EXPERIMENTAL ASTRONOMY*, Vol *11*, 23, 2001.

2 Aschwanden, M. J., Alexander, D., Flare Plasma Cooling from 30 MK down to 1 MK modeled from Yohkoh, GOES, and TRACE observations, *SOLAR PHYSICS*, 204, 91, 2001.

3 Aschwanden, M. J. Radio Frequency-Tomography of Solar Flares, AMERICAN ASTRONOMICAL SOCIETY MEETING 200, #49.05, 2002

4 Andrews, M. D., Lasco and EIT Observations of the Bastille day 2000 Solar Storm *SOLAR PHYSICS*, Vol 204, 179, 2001.

5 Caroubalos, C. *et al* ARTEMIS IV Radio Observations of the 14 July 2000 Large Solar Event, *SOLAR PHYSICS*, 204, 165, 2001.

6 Liu, Y.; Zhang, H. Q. Analysis of a delta spot *ASTRONOMY AND ASTROPHYSICS*,, 386, 646 2002

7 Wang, S., *et al*, Broadband Radio Bursts and Fine Structures during the Great Solar Event on 14 July 2000 *SOLAR PHYSICS*, 204, 153, 2001.

8 Zhang, H. Magnetic field, helicity and the 2000 July 14 flare in solar active region 9077 *MNRAS*, 332, 500, 2002

9 Bieber, John W.; *et al*, Energetic Particle Observations during the 2000 July 14 Solar Event *ASTROPHYSICAL JOURNAL*., Vol 567, 622, 2002

10 Wang, Shujuan; *et al*, Broadband Radio Bursts And Fine Structures During The Great Solar Event On 14 July 2000 *SOLAR PHYSICS*, 204, 155, 2001.

11 Reiner, M. J *et al* ., Bastille Day Event: A Radio Perspective Solar Physics,204,121, 2001.

12 Mc Lean, D.J., Labrum, N.R., *Solar Radiophysics*, Cambridge University Press, Cambridge, 1985

13 Bougeret, J.-L., Steinberg, J.-L., A new scattering process above solar active regions - Propagation in a fibrous medium *ASTRONOMY AND ASTROPHYSICS*, 61, 177, 1997.

14 Isliker H., *et al*, A stochastic model for solar type III bursts *ASTRONOMY AND ASTROPHYSICS*, 336, 371, 1998.

15 Chernov, G. P.; Yasnov, L. V., On the Zebra Structure in the Frequency Range near 3 GHz, *CHINESE JOURNAL OF ASTRONOMY & ASTROPHYSICS*, 1, 525, 2001

16 Jiricka, K.; *et al*. Global statistics of 0.8-2.0 GHz radio bursts and fine structures observed during 1992-2000 by the Ondrejov radiospectrograph *ASTRONOMY AND ASTROPHYSICS*, 375, 243, 2001.

17 Newkirk, G., The Solar Corona in Active Regions and the Thermal Origin of the Slowly Varying Component of Solar Radio Radiation. *ASTROPHYSICAL JOURNAL*. 133, 983, 1961

18 Tlamicha and Karlicky The velocities of type II solar radio bursts *ASTRONOMICAL INSTITUTES OF CZECHOSLOVAKIA, BULLETIN*, 27, 6, 1976

19 Garcia, H. Temperature and emission measure from GOES soft X-ray measurements *SOLAR PHYSICS*, 154, 275, 1994

20 Kurt, V. G *et al*. H., Multi-Wavelength Analysis of the March 26, 1991 Solar Flare and Relation of Spatial and Temporal Characteristics of Ha Emission to the Dynamics of the Magnetic Field and Charged Particle Acceleration in *High Energy Solar Physics -- Anticipating HESSI* ASP Conference Series, vol.206, Ramaty R. and Mandzhavidze N., eds, pp. 426-438, 2000

21 Klein, K.-L.; *et al* ., Coronal electron acceleration and relativistic proton production during the 14 July 2000 flare and CME *ASTRONOMY AND ASTROPHYSICS* , 373:1073, 2001.