Acceleration in solar corona by Alfvén waves

Khalil Daiffallah[1], Fabrice Mottez[2]

[1]Observatory of Algiers, CRAAG, Route de l'Observatoire, BP 63, Bouzaréah 16340, Algiers, Algeria

[2]LUTH, Observatoire de Paris Meudon / CNRS / Université Paris Diderot

Email: k.daiffallah@craag.dz

1-Motivation

Acceleration of particles even in the absence of solar flares or coronal mass ejections is still a current problem. It is widely believed that Alfvén waves can be responsible of acceleration and heating of high-speed solar wind streams.

In this work, we look at a process that can produce parallel electric fields to the background magnetic field on a small spatial scale. These fields can then accelerate electrons. These parallel electric fields are often associated with regions of plasma cavities (Fig. 1, 2). In the solar corona, there are currently no direct observations of electric fields, but multi-frequency observations with the Nançay radioheliograph have shown that coronal regions where radio noise storms are emitted (Fig. 3) present very strong density contrasts [4]. We use an electromagnetic particle-in-cell (PIC) simulation code [2, 3] to study the interaction of Alfvén waves with a solar inhomogeneous plasma.

2-Observations

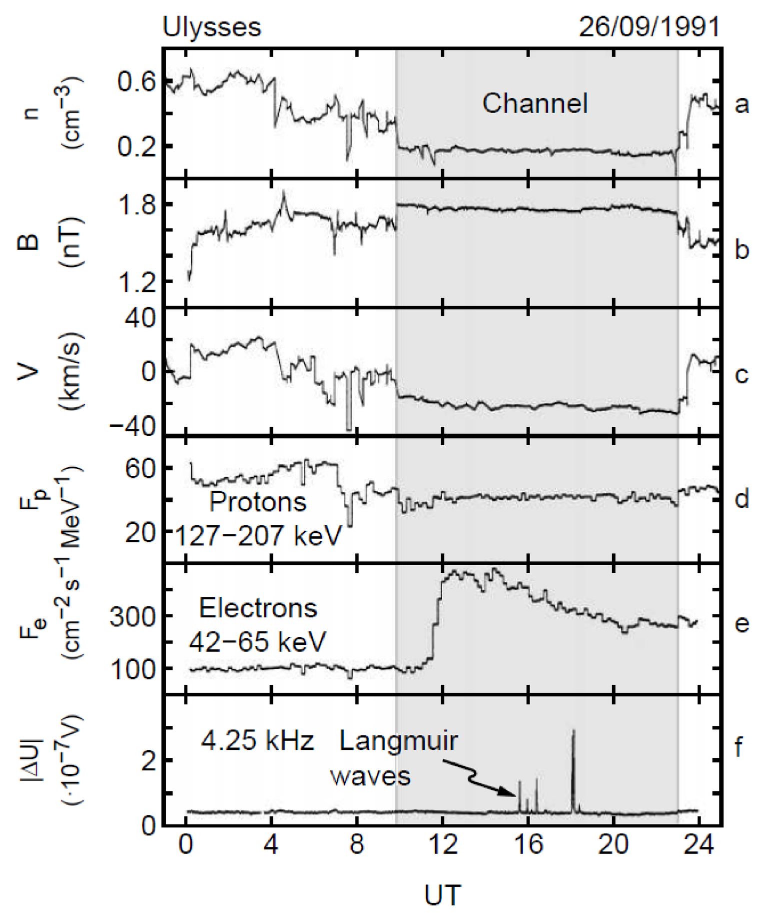

Figure 1: A long channel where the density decreases observed in the interplanetary medium by ULYSSE (Buttighoffer, 1998)

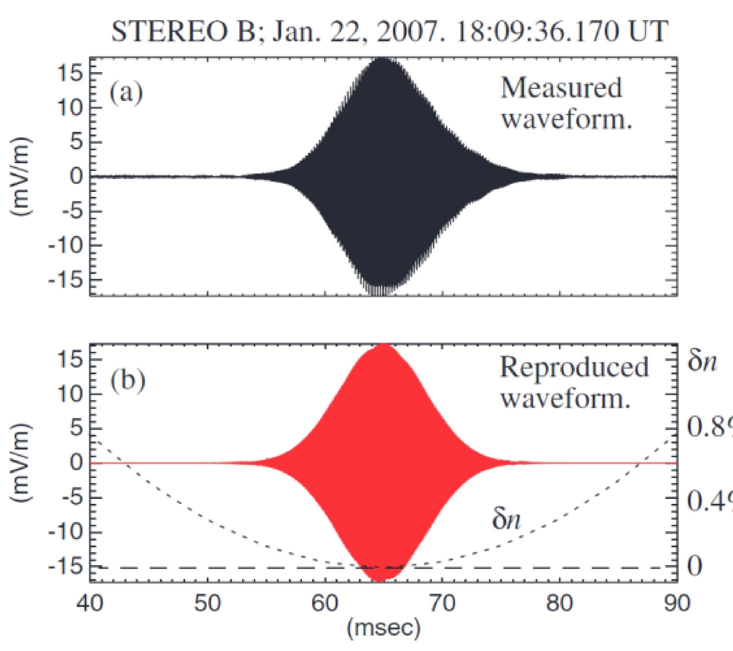

Figure 2: Langmuir waves observed by STEREO B inside cavity in the interplanetary medium (Ergun et al, 2008)

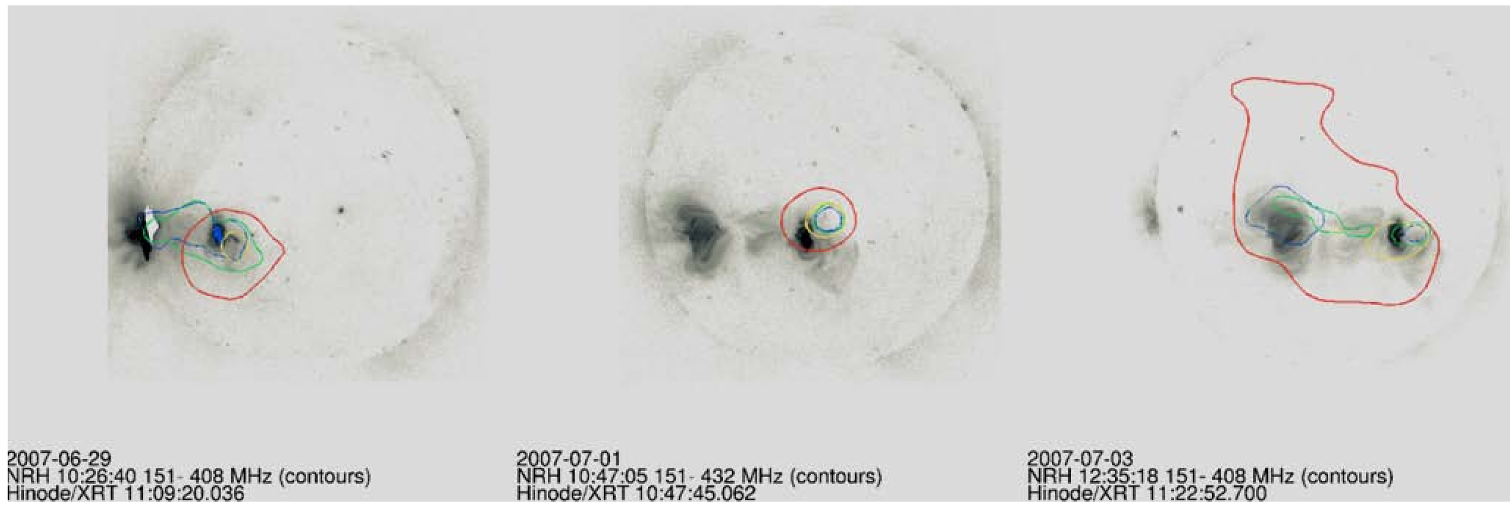

Figure3: Negative images in X-ray of the solar disk taken by Hinode XRT. The superimposed contours are an emission of radio noise storms (Blue = 408 MHz, Green=327 MHz, Yellow = 237 MHz). Del Zanna et al. 2011.

3-Model and Simulation setup

The code is in 2-D space (x, y), and 3-D field and velocity components. The physical variables used in the code are all dimensionless. The simulation box $L_x \times L_y$ is a grid of 1024×256 cells having an individual size of one Debye length. We have fixed $m_i/m_e = 100$ and we take $T_e = T_i$.

The background magnetic field is along the x direction and its intensity is given by the ratio $\omega_{ce}/\omega_{pe} = 0.315$. We have initialized a low frequency right-hand polarized wave which propagates from left to right and has no associated parallel electric field. The perturbation consists of a sinusoidal perpendicular magnetic field B of amplitude $\delta B/B$. With a ratio $\omega/\omega_{ci} = 1.317$ for simulation 1 (Fig. 6) which corresponds to the electron cyclotron propagation branch, and $\omega/\omega_{ci} = 0.54$ for simulation 2 (Fig. 7) which corresponds to Alfvén wave. The plasma cavity has an infinite length (x) with a Gaussian profile in the transversal (y) direction (Fig. 4). The simulations are run over 2048 time steps, where $\Delta t = 0.2$.

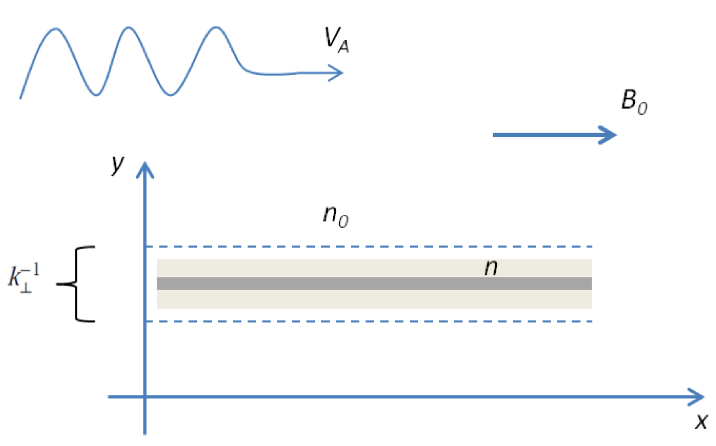

Figure 4: Propagation of Alfvén wave (V_A) with presence of parallel background magnetic field B_0 and transversal density cavity n in x-y plane.

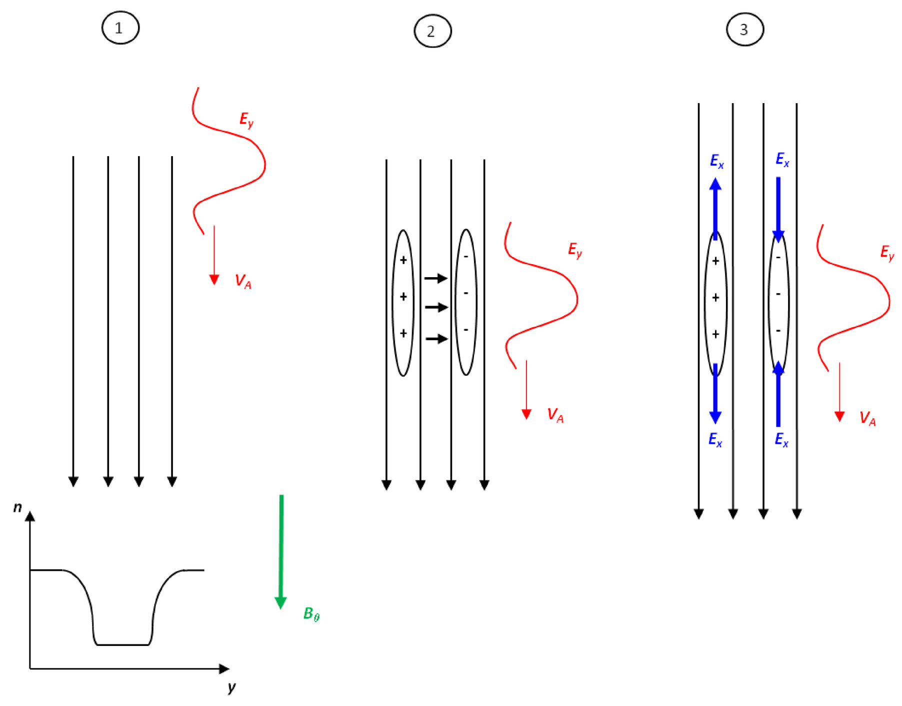

Figure 5: An illustration showing the process of formation of the parallel electric fields: (1) Alfvén wave arrive on density depletion, (2) polarization drift gives rise to electric charges separation in cavity, (3) electric charges gives rise to parallel electric field.

4-Parallel electric field

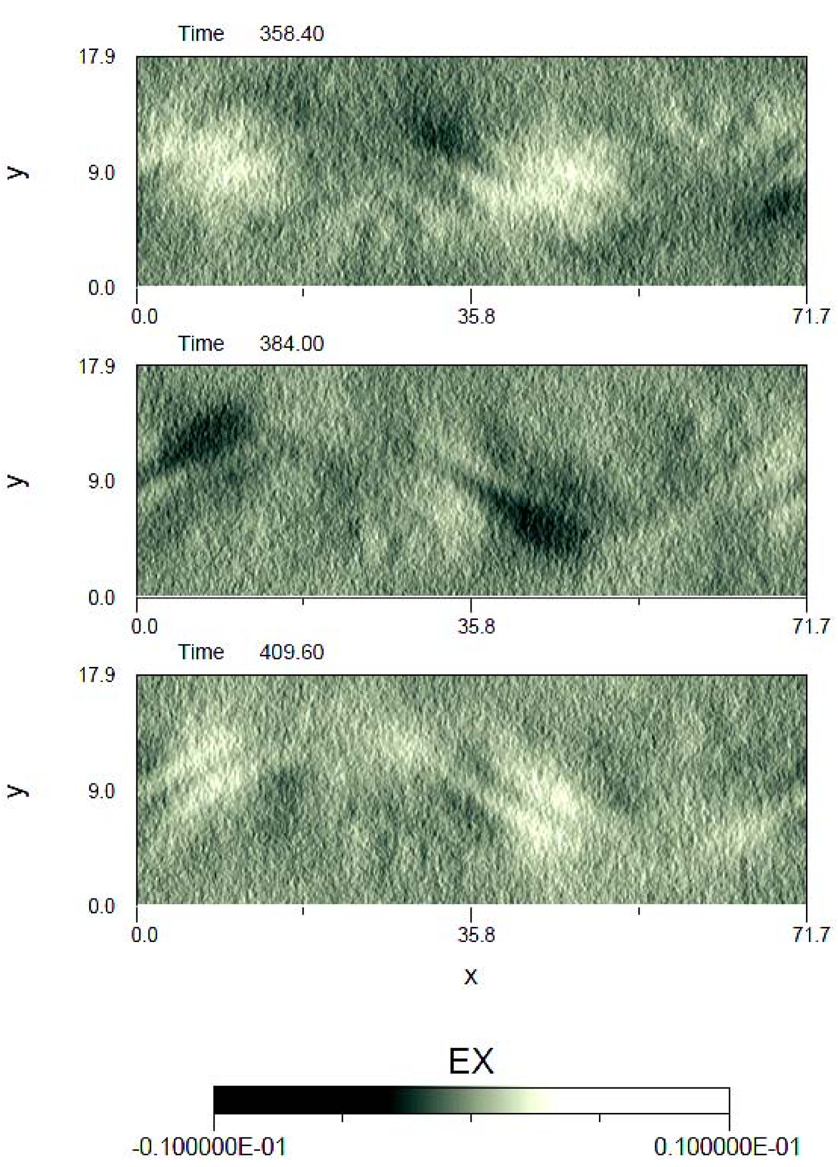

Figure 6: Snapshots from t = 358.4 to t = 409.6 of the parallel component of electric field $E_x(x, y)$.

The figures 6 and 7 show the parallel electric field structure in 2D at three different times. Figure 6 corresponds to a simulation with a cavity of moderate amplitude, and figure 7 to a simulation with a very deep amplitude and a less intense incident wave. In both cases, a parallel electric field is created in the density gradient regions (Fig.5). In the first case, the typical size of the electric structure is those of the incident wave. In the second case, we observe smaller-scale electrostatic structures along the cavity. The nature of these structures is currently under investigation. We notice that they have some analogies with the coherent structures observed in the Earth auroral zone acceleration regions. They might be triggered, as in the Earth auroral zone, by the interaction of the accelerated electrons with the ambient plasma.

5-Possible link to radiation sources

The auroral regions of acceleration are intense sources of long lasting electromagnetic radiation (Auroral Kilometric Radiation). It has been shown that the electric coherent structure play an important role in their generation. We suggest that the coherent structures simulated in the present study could also generate electromagnetic waves. In particular, they might be the source of radio noise storms emissions observed in solar corona. More theoretical investigations and simulations are needed in this direction. This study might be of interest with future space probes like Solar Orbiter (ESA) and Solar Probe plus (NASA).

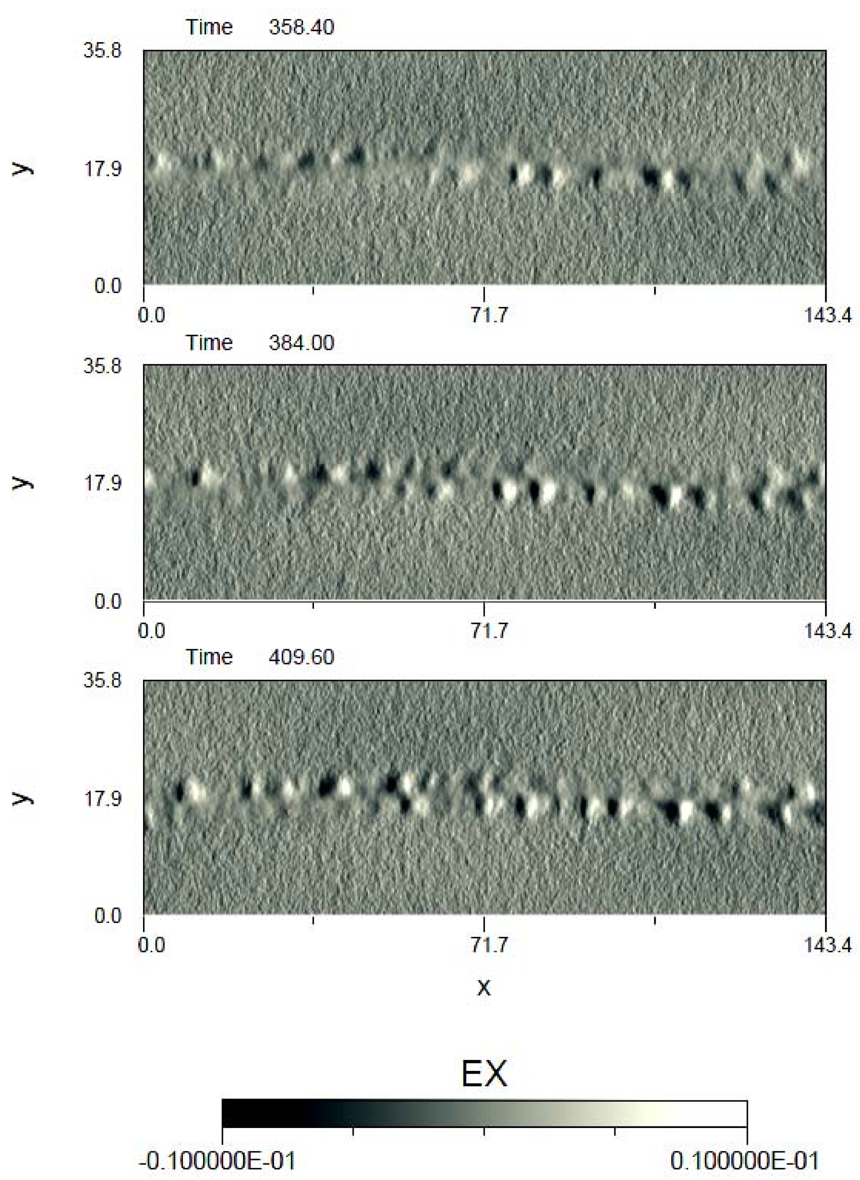

Figure 7: Snapshots from t = 358.4 to t = 409.6 of the parallel component of electric field $E_x(x, y)$.

6-References

[1] Hollweg, J, V., *J Geophys Res*, vol. 91, pp.4111–4125, 1986

[2] Mottez, F., Adam, J, C., and Heron, A., *Computer Physics Communications*, vol. 113, pp.109-130, 1998

[3] Mottez, F., Génot, V., *J Geophys Res*, vol. 116, 2011

[4] Raulin, J, P., Klein, K.-L., *Astron. Astrophys*, vol. 281, pp.536-550, 1994

European Planetary Science Congress 2012 , 23-28 September 2012, Madrid, Spain

Poster Program MG5: Planetary, Solar and exoplanetary radio emissions: P115 EPSC2012-103