EPSC Abstracts
Vol. 7 EPSC2012-103 2012
European Planetary Science Congress 2012

Acceleration in solar corona by electromagnetic ion cyclotron (EMIC) waves

K. Daiffallah (1), F. Mottez (2)
(1) Observatory of Algiers, CRAAG, Algeria (2) LUTH, Observatoire de Paris Meudon / CNRS / Université Paris Diderot
(k.daiffallah@craag.dz/ Fax: +213-21-904458)

Abstract

We investigate the process of acceleration of electrons in the solar corona by the propagation of EMIC waves along a density cavity with density gradients perpendicular to the background magnetic field. We use 2.5-D electromagnetic particle-in-cell simulation code. Simulations show that EMIC waves in interaction with a cavity give rise to a strong local electric field accelerating electrons in the direction of the magnetic field. Non-linear small-scale electrostatic structures are observed inside the deepest cavities, that present similarities with coherent structures observed in other regions of acceleration, as, for example, the Earth auroral zone acceleration regions. As the Earth auroral zone acceleration regions are strong sources of electromagnetic waves, it is possible that the acceleration regions are the sources of radio emissions in the Solar corona.

1. Introduction

Acceleration of particles even in the absence of solar flares or coronal mass ejections is still a current problem in space exploration. It is widely believed that the resonant absorption of electromagnetic ion cyclotron (EMIC) waves is one of the main mechanisms for the acceleration and heating of high-speed solar wind streams [1]. Also, EMIC waves are often used to explain ^{3}He-rich events in impulsive flares in the solar corona [5]. 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 depletion of density or plasma cavities. 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 present very strong density contrasts [4]. We use an electromagnetic particle-in-cell (PIC) simulation code (described in [2, 3]) to study the interaction of EMIC waves with a solar inhomogeneous plasma.

2 Simulation model and parameters

The code is in 2-D space (x, y), and 3-D field and velocity components. It is periodic in both directions. The physical variables used in the code are all dimensionless. In all of these simulations, we take $T_e = T_i$. 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 the ratio ion to electron mass ratio to $m_i/m_e = 100$. The background magnetic field is along the x direction and its intensity is given by the electron cyclotron to plasma frequencies ratio $\omega_{ce}/\omega_{pe} = 0.315$. We have initialised a low frequency right-hand polarised wave which propagates from left to right and has no associated parallel electric field. The perturbation consists of a sinusoidal perpendicular magnetic field δB of amplitude $\delta B/B$. Its polarisation is derived from the cold plasmas theory, and in set in the initial conditions of the simulations. With a wave frequency to ion cyclotron frequency ratio $\omega/\omega_{ci} \approx 1.317$, it corresponds to the EMIC propagation branch. The simulations are run over 2048 time steps, where $\Delta t = 0.2$. The plasma cavity has an infinite length (x) with a Gaussian profile in the transversal (y) direction.

3 Parallel electric fields

The figures 1 and 2 show the parallel electric field structure in 2D the simulation domain at three different times. Figure 1 corresponds to a simulation with a cavity of moderate amplitude, and Figure 2 to a simulation with a very deep amplitude and a less intense incident wave. In both cases, a parallel electric field is

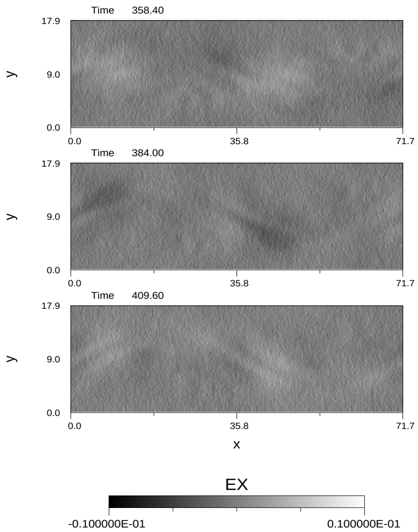

Figure 1: Snapshots from $t = 358.4$ to $t = 409.6$ of the parallel component of electric field $E_x(x, y)$.

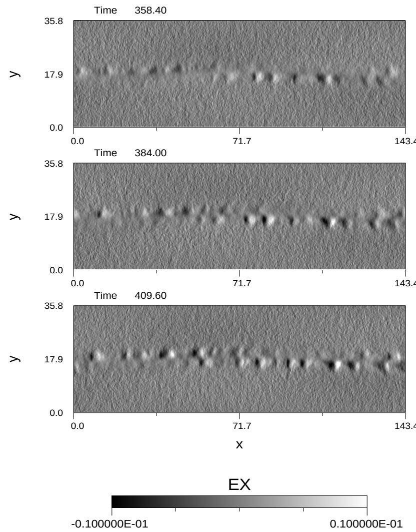

Figure 2: Snapshots from $t = 358.4$ to $t = 409.6$ of the parallel component of electric field $E_x(x, y)$.

created in the density gradient regions. These field are efficient electron accelerators. In the first case, the typical size of the electric structure is those of the EMIC 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.

4. 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).

References

[1] Hollweg, J, V.: Transition region, corona, and solar wind in coronal holes, J Geophys Res, vol. 91, pp.4111–4125, 1986

[2] Mottez, F., Adam, J, C., and Heron, A.: A new guiding centre PIC scheme for electromagnetic highly magnetized plasma simulation, Computer Physics Communications, vol. 113, pp.109-130, 1998

[3] Mottez, F., Génot, V.: Electron acceleration by an Alfvénic pulse propagating in an auroral plasma cavity, J Geophys Res, vol. 116, 2011

[4] Raulin, J, P., Klein, K.-L.: Acceleration of electrons outside flares: Evidence for coronal evolution and height-extended energy release during noise storms, Astron. Astrophys, vol. 281, pp.536-550, 1994

[5] Temerin, M., Roth, I.: The production of ^{3}He and heavy ion enrichment in ^{3}He-rich flares by electromagnetic hydrogen cyclotron waves, Astrophys J, vol. 391: pp.105–108, 1992