ION CYCLOTRON INSTABILITY AND ELECTRON ACCELERATION IN CORONAL MAGNETIC FLUX TUBES *

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Part of the energy of low solar corona may be released and converted to plasma energy that may be the dominant source of solar flares [1]. Recently, many physical mechanisms have been proposed to accelerate ions and electrons [1]–[3]. In the magnetic mirror device of fusion research , ion cyclotron instability and the energetic ion losses have been discovered and the plasma becomes electron rich.

In this paper, we discuss the ion cyclotron instability and electron acceleration in coronal magnetic flux tubes, which are very similar to what happened in magnetic mirror devices .

These accelerated electrons and ions are nonthermal particles. They are injected into magnetc flux tubes which form a magnetic mirror configuration during the time of solar flare activity in the lower corona.

The plasmas in the Magnetic flux tubes are composed by a low-temperature thermal background and a loss cone distribution plasma with larger perpendicular kinetic energy.

The free energy of nonthermal plasma can excite quasi-electrostatic cyclotron instabilities. Electrostatic cyclotron waves have a rather high frequencies ($w \approx l w_{cs}$) and a perpendicula wavelength $\lambda_\perp < a_s$, where l represents the harmonic number, w_{cs} and a_s are the cyclotron frequency and gyroradius of the particles of species s.

The threshold of the cyclotron instability can be estimated as:

$$w_{pe}^2 > l^2 w_{cs}^2 \tag{1}$$

where w_{pe} is the electron plasma frequency. The range of density is given by equation (1). Besider equiation (1) there exist other two necessary conditions for cyclotron instability, which can be obtained:

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$$a_s > 2\lambda_\perp^2 \tag{2}$$

and

$$1 - q_s > (1 - q_s)_{min} \tag{3}$$

where $q_s = n_{0s}/(n_{0s}+n_{fs})$, n_{0s} and n_{fs} are the densities of the thermal background plasma and the nonthermal plasma respectively, n_{fs}/n_{0s} is much less than 1. Equation(2) is consistent with the condition described in paper[6] and [7].

Our numerical results show:

(1) The higher harmonics, the instability occurs easier than the lower harmonics.

(2) The ion cyclotron mode is easier to be excited than the electron cyclotron mode because the density of energetic ions is much larger than that of energetic electron.

After the ion cyclotron instability takes place, an evolution of the velocity distribution of nonthermal particles occurs [8].Ions diffuse quickly into the loss cone and lost, therefore the electric potential of the plasma becomes negative. Electrons are continuously accelerated by electric field and lost from ends of the magnetic flux tube.

In the process that the growth rates approach saturation, except the very short time at the begining, the electric potential increases slowly. The energy of the accelerated electron can reach several hundred keV. These electrons can produce a microwave bursts, with time scale in the order of second, and radiate hard X rays. The mechanism of electron acceleration can also be applied to the physical processes of magnetic flux tubes of the lower corona.

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