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THE EFFECT OF PARALLEL CURRENTS ON AURORAL MICROPULSATIONS

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Field aligned currents play an important role in the global coupling between the magnetosphere and the ionosphere and in their relationship to the auroral phenomena. Moreover, there exists evidence that resonant oscillations are related to large-scale Birkeland currents.[9] The spatial confinement of the field-aligned currents forms an inhomogeneous system susceptible to low-frequency oscillations, which can be excited due to periodic variations in the solar wind pressure or to the Kelvin-Helmholtz (KH) instability. In this paper we present a study of ultralow-frequency (ULF) oscillations in an inhomogeneous magnetic field formed by a large-scale current. We investigate the effects of the field-aligned currents on the generation of localized Alfvén waves. The field oscillations are described by an eigenvalue wave equation which includes the effects of the field aligned currents, and which produces a discrete spectrum of Alfvén waves. These waves are observed mainly in three regions of the magnetosphere: in the magnetosheath, in the polar cusp and in the plasmasphere. In the present study we limit our investigation to the auroral region. Micropulsations are long-period (usually of the order of minutes) fluctuations of the Earth's magnetic field observed for a large number of wave-periods. An important question is the relation between the micropulsations to other observable quantities on the auroral field lines. A correlated study of precipitating electrons, auroral emissions, Birkeland currents and the orientation of the interplanetary magnetic field suggests that the precipitating electrons carry simultaneously the Birkeland current and cause the auroral emissions. An analysis of a magnetic field, electric field, X-ray and particle data concluded that wave-particle interaction is a source of periodic variations in the electron precipitation [6; 5]. Oscillations in UV emissions were conjectured as due to a standing Alfvén wave driven by a large-scale wave in the boundary layer. The theories of magnetic pulsations deal with the excitation mechanisms of the waves and different aspects of resonance with particles [3] . The long-period pulsations are excited by KH instability at the outer magnetosphere or by the pressure gradient of the ring current. Strong observational evidence was presented that Pc5 pulsations on the dawn flank are driven by the KH instability in the low-latitude boundary layer [12].

Chen and Hasegawa [3] proposed a micropulsations model, based on a steady state oscillation of a resonant local field line which is excited by a monochromatic surface wave at the magnetosphere. A coupled wave equation between the shear Alfvén wave representing the field-line oscillation and the surface wave was derived and solved in dipole coordinates. They obtained the frequency, the polarization, the orientation angles of the major axes, and the ellipticity as a function of magnetospheric parameters. Kivelson and Southwood [5] proposed a micropulsation model which delineated the observed discrete spectra. They used a model of an inhomogeneous plasma in the terrestrial magnetosphere and in the framework of the MHD equations obtained fast eigenmode solutions with quantized energy. They also suggested [6], that for each eigenfrequency the equation contains discrete points where the field line resonance occurs. Lee and Lysak [8] studied the ULF waves at the three-dimensional dipole magnetosphere. The properties of the coupled compressional and transverse wave-fields were found to depend on the longitudinal size of the impulse which impacts at the magnetopause. However, none of these models takes into account the ULF wave propagation in the presence of currents aligned to the ambient magnetic field. Field-aligned currents are very important in the study of the magnetized plasmas in the solar-terrestrial environment. The present model considers currents parallel to the Earth's magnetic field and investigates the effect of these currents on the micropulsations. We consider an inhomogeneous, magnetized, current-carrying plasma and study the predominantly transverse eigenmodes. Solutions of the Hain-Lust equation in rectangular coordinates result in the profiles of the displacement ξ and show that the values of the excited wave frequency by the parallel currents is around the discrete Alfvén and agree well with the PC5 micropulsation. Assis and Tavares [2], have shown that parallel currents are an important feature of the plasmapause region. They proposed to access the problem of non-inductive DC current generation by plasma waves in the terrestrial magnetosphere and the reasonable result obtained of the efficiency of the KAW (kinetic Alfvén waves) provides the necessary input to our work. We model the auroral configuration as a box of a current carrying magnetized plasma. This model describes the localized aspects of Alfvén waves excited in the auroral region. The existence of the Birkeland currents replaces the homogeneous background by the globally inhomogeneous confined plasma. The ambient magnetic field is approximated by straight field lines with a constant, field-aligned current describing the Birkeland currents [9]. We assume a scale length L of the magnetic field perpendicular to the ambient field, and impose as boundary condition the vanishing of the perturbed displacement at large distances, several times L. This model is able to show how the inhomogeneous magnetized plasma can support the discrete eigenmodes.To simulate parallel currents in the auroral region we choose a magnetic field profile which varies like sech(x/L) in the perpendicular direction to the ambient field We assume that this field creates parallel currents to understanding of the discrete Alfvén modes out side the field of space physics refer to [12].These modes have similar behaviour to the ones that there are solutions of the Hain -Lust equation around the singular points of the marginal equation, the so-called Suydam modes explain about these modes in [4].

Choosing the perturbed linear plasma displacement of the MHD equation ξ_x along the perpendicular direction x as $\xi(x)\exp(ik_y y + k_z z - \omega t)$ we obtain:

$$\left(\frac{N}{D}\xi'\right)' + \left(\sigma^2 - f^2b^2\right)\xi = 0 \tag{1}$$

where $N = \left(\sigma^2 - f^2b^2\right)\left[(b^2+c^2)\sigma^2 - f^2b^2c^2\right]$, $D = \sigma^4 - k^2(b^2+c^2)\sigma^2 + k^2f^2b^2c^2$, $c = (\gamma p/\rho)^{\frac{1}{2}}$, $b = B/\rho^{\frac{1}{2}}$, $\sigma = -\omega^2$, $g = ik_y$, $f = ik_z$, $k^2 = k_y^2 + k_z^2$. Equation [1] is singular if $N/D = 0$ and $N/D = \infty$. The quantities γ, p and ρ are the adiabatic constant, plasma pressure and mass density, respectively. The equilibrium field $\vec{B}$ is chosen as $B = (0, B_{0y} sech(\frac{x}{L}), B_z)$. In Eq. [1] we normalized the coordinate x and the displacement ξ to L, the velocities to the Alfvén velocity at $x = 0$, $V_A(0)$, and the frequencies to $V_A(0)/L$. We choose $k_y = 2\pi/\lambda$ and $k_z = 2\pi/L$ where λ is the wave length. Figure 1a-c shows the profiles (in unnormalized units) of the total magnetic field $B(x)$, the current J(x), and the pressure $p(x)$ which satisfies the equilibrium equation for the total pressure, $p + B^2/2 = const$ with $B^2 = B_z^2 + B_y^2$. The normalized quantities chosen are $B_y(0) = 0.8$, $B_z(0) = 0.1$, $\lambda = 0.003$. The current is formed due to the gradient in the transverse component of the magnetic field. Two of the three profiles can be choose. In order to obtain the normalized eigenvector ξ for a given eigenmode ω,we use the shooting method with the boundary conditions at $x = -3L$ and $x = 3L$. The value of β is chosen between 0.1 and 1.0. We convert the eigenvalue equation (1) into two first order ordinary differential equations

$$y_1' = y_2 \tag{2}$$

$$y_2' = -(D/N)[(N/D)'y_2 + (\sigma^2 - f^2b^2)y_1] \tag{3}$$

and solve for the vector $(y_1, y_2) = (\xi, \xi')$. The singularity condition of eq. [1] gives the eigenvalues σ_s which define the Alfvén continuum and σ_A which define the slow wave continuum. The first of these eigenmode is $\sigma = fb$ which is the dispersion relation in homogeneous plasma, but in the inhomogeneous media this gives the Alfvén continuum. Figure 1d shows the perturbed linear displacement ξ as a function of the coordinate x for $\sigma = 1.2fb$. For different values in the vicinity of this σ there are no solutions of the eigenvalue equation with the prescribed boundary conditions. In summary we show how the parallel currents affect the micropulsations. These preliminary results show that the frequencies obtained from the Hain-Lust equation agree with the well-known Pc-5 pulsations that are excited in the presence of the field lines currents.

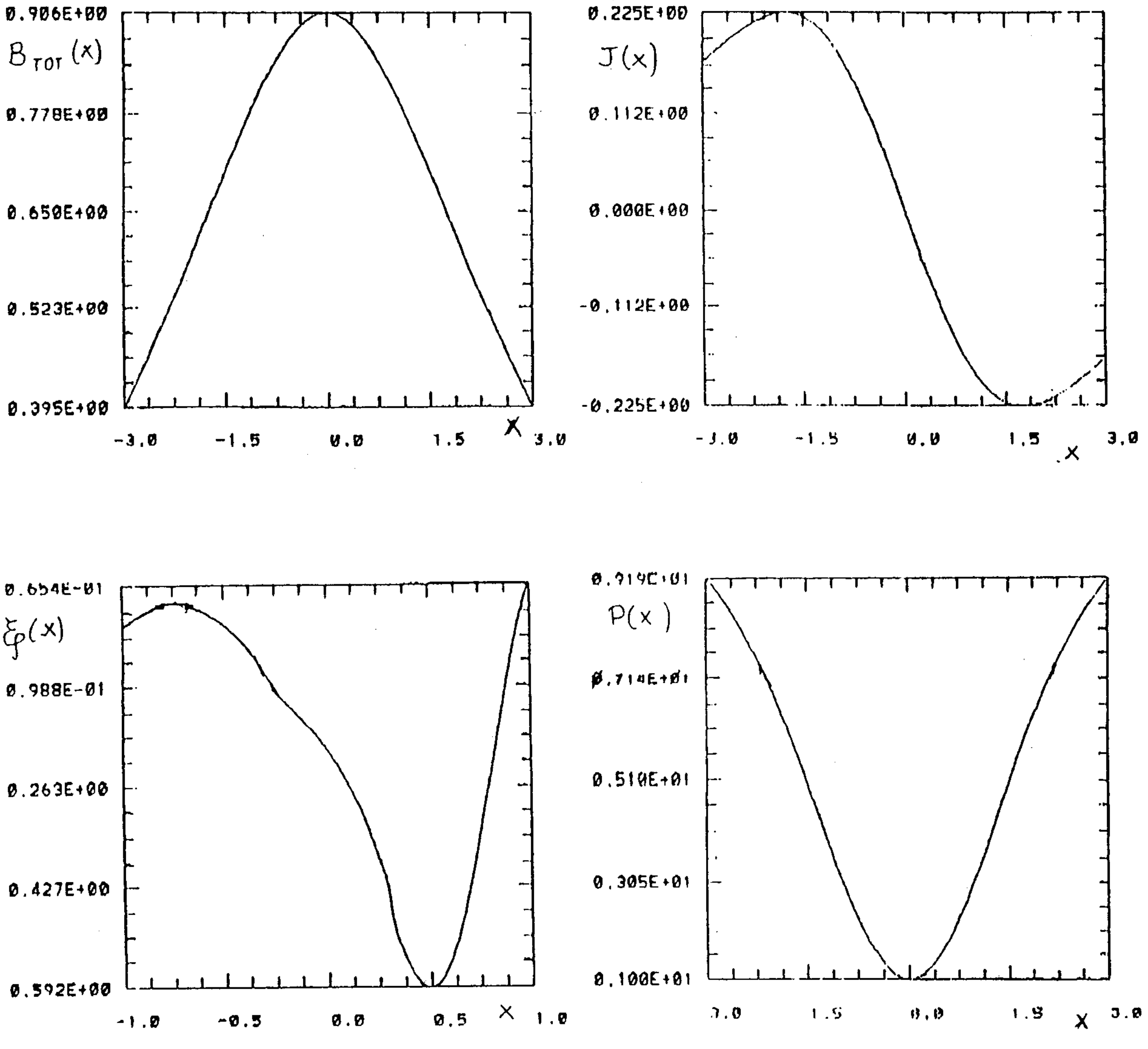

Fig.1 Calculated profiles of magnetic field (a), current (b), pressure (c) and the eigenmode (d) vs x (all the quantities are in arbitrary units).

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