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(NASA-CR-171537) WAVE/PARTICLE INTERACTIONS IN THE PLASMA SHEET Final Report (Colorado Univ.) 7 p HC A02/MF A01 CSCL 03B

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WAVE/PARTICLE INTERACTIONS IN THE PLASMA SHEET

The most frequent and intense waves observed in the geomagnetic tail region are short wavelength electrostatic broad band emissions. Early observations of these waves were made by Scarf et al. (1974) and Gurnett et al. (1976) using IMP 7 and 8, respectively. Gurnett et al. found a broad frequency range for the waves, from about 10Hz to several kHz, with an average r.m.s electric field amplitude of about 1mV/m. Other less frequent and less intense wave modes were also identified: magnetic noise bursts and electrostatic electron-cyclotron waves. The highest frequency of occurrence of the electrostatic noise was found by Gurnett et al. in the region near the plasma sheet boundary when anisotropic fluxes of ions streaming either earthward or anti-earthward were present.

In a more recent study, Grabbe and Eastman (1984), using ISEE data, confirmed many of the suggestions made by Gurnett et al. (1976). Namely, that the waves were usually observed during times of ion streaming and that the intensity and frequency range was maximum in the plasma sheet boundary layer (Eastman et al., 1984) and fell off dramatically in the tail lobe and central plasma sheet regions. Furthermore, it was suggested that increases in the electron and ion temperature in going from the tail lobe to the central plasma sheet were a result of scattering of resonant, boundary layer plasma.

Both earthward and anti-earthward streaming ions of keV energies have been observed within the plasma sheet boundary layer (Lui et al., 1977; De Coster and Frank, 1979; Williams, 1981). These particles possibly result from energization in the tail current sheet (Lyons and Speiser, 1982). They are dominantly protons with streaming speeds of 500–1,500 km/sec, temperatures of 0.1 - 1keV, and densities $\lesssim$ 1cm^{-3}.

Sharp et al. (1981, 1982) observed cold ion streams in the plasma sheet region. These appear to be of ionospheric origin and to have been accelerated in association with auroral phenomena. The composition of the cold streaming ions are primarily H^+ and O^+. Typical number densities are $\lesssim$ 0.1 cm^{-3}, temperatures of 50eV or less, and streaming speeds $\lesssim$ 300 - 1,500 km/sec. Figure 1 is a schematic of the noon-midnight meridian cross section of the earth's magnetosphere emphasizing the suggested importance of both ion beams within the plasma sheet boundary layer.

Grabbe and Eastman (1984) proposed that the waves are a beam driven instabillity of the plasma sheet boundary layer. They modeled the plasma sheet particle population by streaming > 1keV ions, cold stationary ions (temperature ~ 100eV) and several hundred eV stationary electrons. They only considered the stability of ion beams with thermal energies about 4x10^{-4} smaller than the beam energies. For several keV beam energies, this gives thermal energies of a few eV, which is very much colder than the warm ion beams in the plasma sheet boundary layer (Eastman et al., 1984). These temperatures, however, are not unreasonable for the cold ionospheric ion beams.

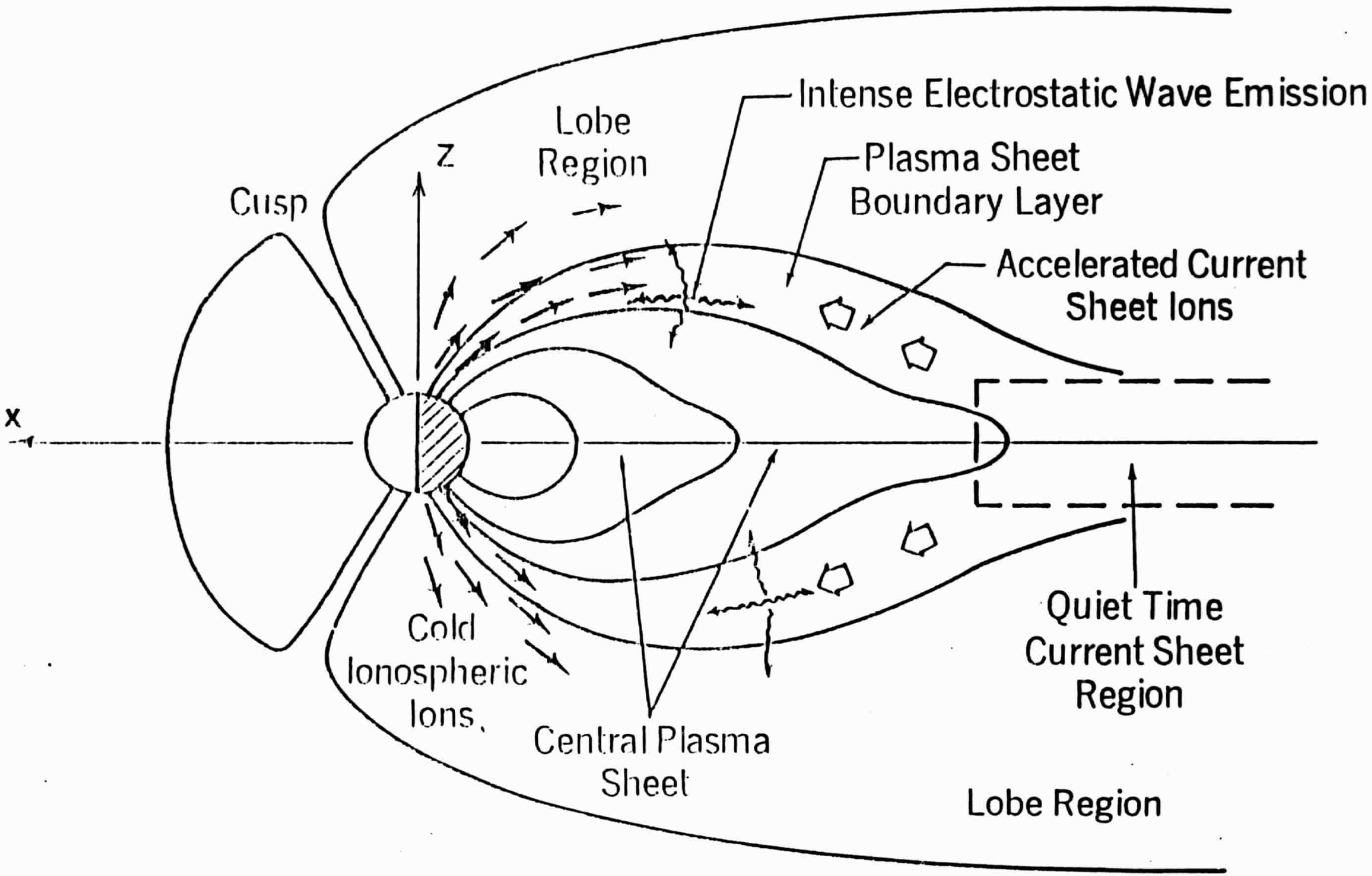
Intense Electrostatic Wave Emission
Plasma Sheet
Boundary Layer
Accelerated Current
Sheet Ions
Lobe
Region
Z
Cusp
X
Cold
Ionospheric
Ions.
Central Plasma
Sheet
Quiet Time
Current Sheet
Region
Lobe Region

FIGURE 1

In a recent study, Dusenbery and Lyons (1985) investigated the generation of electrostatic noise in the plasma sheet region of the geomagnetic tail. The wave intensity of the noise is observed to peak in the plasma sheet boundary layer but weaker wave events are frequently observed in the tail lobes and central plasma sheet. This study found that if only warm boundary layer ion beams are present, then no broad band waves were excited. However, if cold ion beams (of ionospheric origin) are present, then a growing wave called the slow beam acoustic mode can be excited. If both hot and cold ion beams are present, then both the fast and slow beam acoustic modes may be unstable with growth rates significantly greater than those for a single cold ion beam.

Dusenbery and Lyons (1985) showed that the magnitude and sign of the slow and fast beam mode growth rates were sensitive to the relative streaming of the hot and cold ion beams. In particular, to get growth, the hot beam velocity must be somewhat smaller (slow mode) or greater (fast mode) than the cold beam velocity. When the beam velocities were comparable, both modes were found to be damped. Even though the peak wave growth of the slow mode was found to be larger than the peak wave growth of the fast mode, the amplification length showed that net wave growth of the fast mode can be comparable to that of the slow mode. Wave growth was also found to be sensitive to the magnitude of the hot ion temperature (growth rate decreases with increasing hot ion temperature), and the ion number density (growth rate decreases with decreasing number density). This study therefore offered an explanation for the peak wave intensity in the plasma sheet boundary layer and weaker intensities in the lobes and central plasma sheet.

The hot streaming ions and electrons resonate with the waves and thus may be heated significantly by both the slow and fast ion beam instability. Such heating may play an important role in the evolution of ion distributions into the hot component of the central plasma sheet. On the other hand, the cold streaming ions determine the wave dispersion but do not resonate with the waves. Thus, the cold streaming ions will be affected very little by the instability. The plasma sheet boundary layer is important in the transport of energy and momentum in the magnetotail (Eastman et al., 1984). Particle transport and wave-particle interactions may play an important role in determining the exact nature of this energy and momentum balance.

At present, work is continuing on the beam acoustic instability. Wave frequencies and growth rates vs. wave normal angle are being plotted; in addition, we are determining the mass dependence of the instability. Knowing the growth rate variation in k-space will give us insight into the wave electric field variation in k-space. We will use this result to evaluate the diffusion coefficients and therefore to solve the quasi-linear diffusion of resonant particles in the presence of either slow or fast ion acoustic waves.

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