PLASMA ELECTRON MEASUREMENTS IN THE OUTER JOVIAN MAGNETOSPHERE

Devrie S. Intriligator

Physics Department, University of Southern California
Los Angeles, California 90007

John H. Wolfe

NASA Ames Research Center
Moffett Field, California 94035

Abstract. The existence of the plasma electrons in the outer Jovian magnetosphere reported by Intriligator and Wolfe [1974] is consistent with 1) the additional pressure needed to supplement the magnetospheric magnetic field in the outer magnetosphere so as to balance the solar wind and interplanetary magnetic field dynamic pressure across the magnetopause, 2) the drastic change in the plasma electron spectrum as soon as Pioneer 10 crossed the magnetopause from the magnetosheath into the magnetosphere, 3) the fact that the instrument aperture was at spacecraft ground, and 4) the fact that beyond ~ 2 AU the continuous observations of all ambient electron fluxes (solar wind electrons, secondary electrons, photoelectrons, etc.) are below the instrument threshold.

The recent analyses of the ATS-6 data reported in Grard et al. [1977] suggest that "on ATS-6 portions of the spacecraft surface which are finished with white paint have been observed to charge differentially and emit secondary electrons." Grard et al. [1977] suggest that similar electrons may have been produced at the high gain antenna reflector and the medium gain antenna on Pioneer 10 and that these may have been the low energy electrons detected by the Pioneer 10 plasma analyzer [Intriligator and Wolfe, 1974; Intriligator, 1975; Intriligator and Wolfe, 1976]. These recent ATS-6 results were not available at the time of our Pioneer 10 analyses and it is possible that they are relevant to the low energy electrons observed by Pioneer 10 in the outer magnetosphere. However, even in light of the ATS-6 results evidence still points toward the presence of ambient low energy electrons and a thermal plasma in the outer Jovian magnetosphere.

1) Pressure balance across the magnetopause. Assuming that the Jovian magnetopause was a tangential discontinuity we [Intriligator and Wolfe, 1974, 1976] calculated the pressure balance across it using the Pioneer 10 plasma parameters [Wolfe et al. 1974] and magnetic field parameters [Smith et al. 1974]. We concluded [Intriligator and Wolfe, 1974, 1976] that additional pressure was needed to supplement the magnetospheric magnetic field in the outer magnetosphere. This pressure could be supplied by an isotropic plasma with $kT \lesssim 500$ eV and with $\frac{1}{2}mV^2 << kT$. We assumed that such a plasma did supply the pressure in the outer magnetosphere. For this low temperature plasma in the outer magnetosphere large charging levels would not be expected. Therefore, we used the Pioneer 10 measurement of the low energy electrons in the outer magnetosphere (with an energy of ~ 4 eV and an associated temperature of 5×10^4 °K); assuming $T_e \sim T_i$ we calculated a number density of a few particles cm^{-3} (and a plasma beta ~ 1) if there were a thermal plasma in the outer magnetosphere. We "cautioned that the above value of beta and the corresponding number density is considered to be an upper limit since the possible magnetospheric pressure contribution from the observed nonthermal plasma electrons and unobservable energetic electrons between 500 eV and ~ 50 keV has not been accounted for." Kennel and Coroniti [1975] have suggested that an energetic proton component may be present. It is also possible that as suggested by Grard et al. [1977] the observation of the low energy electrons and the associated thermal plasma was not a measurement of the ambient plasma.

2) The drastic change in the plasma electron spectrum as soon as Pioneer 10 crossed the magnetopause from the magnetosheath into the magnetosphere. In our judgment, this observation, which Grard et al. do not discuss, supports the identification of the electrons as ambient electrons associated with a thermal plasma. Note that energetic electrons (E > 50 keV) were observed within the magnetosheath and upstream from the bow shock. However, upstream from the bow shock no thermal electrons were detected. Although suprathermal electrons were observed in the magnetosheath (presumably due to heating by the bow shock) this electron population was not correlated with the highly modulated (~10 hr) energetic electrons which were observed in this region. It should also be noted that the 10 hour modulation of the energetic electrons persisted across the magnetopause, whereas the plasma electrons showed a drastic change in spectra across the magnetopause. This change in the plasma electron spectra showed the absence of a nonthermal tail (this tail is characteristic of the magnetosheath distribution) with a low energy (~4 eV) peak remaining. The latter is consistent with our original [Intriligator and Wolfe, 1974] conclusion for the presence of a thermal plasma in the outer Jovian magnetosphere.

3) The Pioneer 10 plasma analyzer entrance aperture was at spacecraft ground. Grard et al. state that on IMP-2 and OGO-1 the secondary and photoelectrons were deflected into the plasma instruments due to the potential difference between the instrument aperture and the spacecraft ground. This is not the case on Pioneer 10, since on Pioneer 10 (and 11) the instrument aper-

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ture for the plasma analyzer was at spacecraft ground. On Pioneer 10 (and 11) even the plasma analyzer plates [Intriligator and Wolfe, 1976] are equally balanced positive and negative with respect to spacecraft ground. It should also be noted that the plasma instruments flown on Pioneer 10 and 11 were curved plate electrostatic analyzers which are not susceptible to the same type of internally generated secondary and photoelectrons as the instruments flown on IMP-2 and OGO-1. The IMP-2 and OGO-1 instruments are basically ion traps which view the surrounding medium through a series of grids at various potentials.

4) Beyond ~ 2 AU continuous observations of all ambient electron fluxes (solar wind electrons, secondary electrons, photoelectrons, etc.) are below the instrument threshold. The times when solar wind electrons were observed beyond this distance occurred during high density interplanetary events (e.g., the August 1972 events). Therefore, the sudden observation of the low energy electrons in the outer Jovian magnetosphere indicates that there was a definite large increase in the number density in this energy range. It is highly unlikely that this could be due to a sudden very large increase in photoelectrons.

The conclusion that the outer Jovian magnetosphere contains a thermal plasma of the type described by Intriligator and Wolfe [1974, 1976] is supported by the factors discussed above. (Of course, the outer Jovian magnetosphere must contain some type of thermal plasma.) At this time the origin of the plasma and its complete distribution function have not been determined. It is hoped that future spacecraft will carry a set of plasma analyzers that will simultaneously measure convecting and non-convecting plasma ions and electrons throughout the Jovian magnetosphere. These plasma analyzers, with the aid of simultaneous particle measurements which cover the entire energy spectrum ($\gtrsim$ 10 keV/nucleon), plasma wave measurements, and magnetometer measurements, etc., should determine the dynamics of the Jovian magnetosphere and the role of the various particle populations.

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