Comment on 'On Double Current Layers in the Polar Cusp'
by A. Bahnsen, N. D'Angelo, and A. Menecke Hansen

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Bahnsen et al. [1975] have suggested that the double current layers reported by Fredricks et al. [1973] are associated with the Kelvin-Helmholtz instability driven by velocity shears in the polar cusp. This type of mechanism certainly can operate in the polar cusp, given the proper conditions, but we do not agree with the suggestion of Bahnsen et al. [1975] that this mechanism explains the observations of Fredricks et al. [1973]. There are several areas of disagreement with the model involving the number of field-aligned current encounters, the nature of the 'waves' in the cusp, and the inferred stability of the cusp to Kelvin-Helmholtz waves at the time of the Ogo 5 observations. We examine these points below.

The first study of the ULF and VLF waves in the polar cusp showed intense magnetic ULF waves and VLF electrostatic emissions [Russell et al., 1971]. Two types of ULF power spectra were observed: one with power inversely proportional to the square of the frequency both above and below the ion gyrofrequency and one with a cutoff at the ion gyrofrequency. Subsequent examination of the high-resolution magnetic records revealed that the occurrences of the former spectra were associated with irregular purely transverse disturbances in the magnetic field, consistent with either striated or impulsive field-aligned currents, and that occurrences of the latter spectra were associated with the occurrence of ion cyclotron waves [Scarf et al., 1972; Fredricks et al., 1973; Fredricks and Russell, 1973; Kivelson et al., 1973; Russell et al., 1974]. Of importance to the present discussion is the fact that many of these sheets of striated or impulsive currents were seen per cusp encounter. For example, during the first cusp crossing on November 1, 1968, Ogo 5 encountered more than 12 such current bursts (see Table 1 of Fredricks et al., 1973). While Imp 5 plasma measurements [Frank, 1971] and Heos 2 plasma measurements [Paschmann et al., 1974] reveal cusp-aligned flows, the velocity shear layer should occur at the cusp boundary and not repeatedly throughout the cusp. Even the remarkable simultaneous appearance of both upward and downward flowing cusp plasma observed on Heos 2 was detected only once per cusp encounter upon entry to the cusp. Thus simply the number of current encounters observed by Ogo 5 tends to argue against the validity of any velocity shear model as an explanation of the Ogo 5 data.

Nevertheless, since the cusp boundary is a nonuniform plasma region, it is certainly of interest to consider if any generalized kinds of Kelvin-Helmholtz instabilities can explain the observations. However, in this context we feel that the specific form of the Kelvin-Helmholtz instability discussed by Bahnsen et al. [1975] cannot be used to explain the Ogo 5 observations of large amplitude magnetic perturbations for the high-$\beta \approx 10^{-2}$ conditions that were prevalent during the November 1, 1968, cusp encounters.

Bahnsen et al. [1975] discussed a specific form of the Kelvin-Helmholtz instability and related laboratory experiments carried out by D'Angelo and von Goeler [1966]. The experiments were designed to test a theory developed by D'Angelo [1965]. However, as D'Angelo and von Goeler pointed out, this theory was only appropriate for a shear that was sufficiently smooth so that the WKB method could be used. Moreover, the theoretical treatment neglected ion viscosity, Landau damping, and large $\beta$ effects, and all of these conditions were not really fulfilled in the laboratory experiments of D'Angelo and von Goeler. In fact, Smith and von Goeler [1968] demonstrated that the simplified fluid treatment of D'Angelo needs considerable modification to account for the complete plasma effects, and they noted that in the realistic case the maximum growth rate mode is inaccessible to an approximate theoretical treatment. In addition, Dobrowolsky [1972] showed that the $\beta \ll 1$ assumption gives little guidance for the $\beta \approx 1$ case of interest and that the low-$\beta$ electrostatic fluid treatment of D'Angelo [1965] neglects important stabilizing terms. The fact that the actual Ogo 5 cusp encounter near 1250-1320 UT on November 1, 1968, did involve a high-$\beta$ plasma is very evident in Figure 8 of Scarf et al. [1972], where the diamagnetic effects of the plasma show up in the field profile plot. The total plasma $\beta$ for the November 1, 1968, cusp encounters varied from $10^{-1}$ to $10^{-2}$, as noted above, and since $\beta > m_e^2/m_i^2$ (equaling $5.5 \times 10^{-4}$) for all cusp encounters, low-$\beta$ treatments cannot be applied with any confidence. Moreover, since the Ogo 5 measurements involve magnetic perturbations, it is difficult to see how theories and experiments involving electrostatic perturbations can be related directly to the magnetospheric observations.

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References


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