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Detection of a Hot Plasma Component Within the Core Regions of Jupiter's Distant Magnetotail

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We have combined the Voyager 2 low-energy plasma data from the Plasma Science Experiment (PLS) and the magnetic field data from the Magnetometer Experiment (MAG) with the Voyager 2 Low Energy Charged Particle Experiment (LECP) ion data ($E > 28$ keV) for the previously described distant magnetotail observations ($5000 < R < 9000\ R_J$). We show for the first time a definite enhancement of LECP fluxes within the core regions where the PLS densities and magnetic field pressure are lower than surrounding regions, indicating that this hot tenuous plasma is present within the core regions. In general there is a strong anticorrelation between PLS density and LECP fluxes, while a less pronounced anticorrelation between magnetic field pressure and LECP fluxes is observed. Estimates of LECP pressures suggest that this hot plasma will provide the previously described missing pressure in the core if heavy ions dominate the ion composition. The angular dependence of the LECP data indicates a flow of this hot plasma in the anti-Jupiter direction. This outflowing plasma could be the remnant of the magnetospheric wind observed near Jupiter by LECP. On the basis of this preliminary study we have identified the core regions as having similarities to a plasma sheet.

1. INTRODUCTION

Since *Scarf* [1979] and *Grzedzielski et al.* [1981] first suggested that the Voyager 2 spacecraft might enter the distant Jovian magnetotail during its transit from Jupiter to Saturn, numerous publications have reported in situ observational evidence from Voyager 2 that the spacecraft had entered the distant Jovian magnetotail. *Scarf et al.* [1981] and *Kurth et al.* [1982] used data from the Plasma Wave Experiment (PWS) and the Plasma Science Experiment (PLS); *Lepping et al.* [1982] used data from the Radio Astronomy Experiment (PRA) and the Magnetometer Experiment (MAG); *Lepping et al.* [1983*a*] used data from MAG, PLS, and PRA; and *Goldstein et al.* [1985] used MAG and PLS data. Each data set (PWS, PRA, PLS, and MAG) by itself cannot be used as convincing evidence for actual tail entry, but when combined together the evidence for tail entry becomes very convincing. The latter papers by *Kurth et al.* [1982], *Lepping et al.* [1983*a*] and *Goldstein et al.* [1985] have been the most comprehensive to date, and it is the Kurth et al. paper that first coined the name "core" region for those regions within the tail events when the plasma density is lowest, nonthermal continuum radiation is the most intense, evidence for solar wind plasma is totally absent in the PLS measurements, and the magnetic field orientations are taillike in character (approximately aligned along the spacecraft-Jupiter line) versus the interplanetary magnetic field (IMF) direction which is, on average, approximately transverse to the spacecraft-sun line in the ecliptic plane.

Kurth et al. [1982] and later *Lepping et al.* [1983*a*] noted that the plasma pressure plus magnetic field pressure observed by PLS and MAG, respectively, within the core regions was not sufficient to balance the external plasma pressure (i.e., ram and thermal pressure) and magnetic field pressure in the solar wind. Since the core regions are a generally observed phenomenon in the tail sightings, they are in all likelihood a permanent feature of the distant Jovian tail. It appears then that a hot plasma component must be present within the core regions with sufficiently low density ($n \lesssim 10^{-3}$ cm^{-3}) and high temperature ($T \gtrsim 10$ keV) that it could not be detected by the PLS instrument but still provide the required pressure balance. An alternative explanation by *Lepping et al.* [1983*b*] was later introduced, which considered the possibility of a twisting of the tail field lines imparted by the rotational motion of Jupiter such that an outward centrifugal force of the field and plasma within the tail provided the required internal pressure. This twisting motion can be viewed as a circularly polarized Alfvén wave propagating down the Jovian tail. Recently, *Goldstein et al.* [1985] have presented observational evidence for only a slight twisting of the field lines in the near-tail region, using Voyager 1 outbound Jupiter encounter data between 80 R_J and 139 R_J from Jupiter center, and found conflicting and weak evidence for any twisting of the field during the distant tail events observed by Voyager 2.

In this paper, using data from the Low Energy Charged Particle Experiment (LECP) on Voyager 2, we present observational evidence for a hot plasma component within the core regions of the Jovian tail which can provide the required internal pressure balance, if this hot plasma is dominated by heavy ions and thus of Jovian origin. Because of the low densities ($n \sim 10^{-6}$ cm^{-3}) and high temperatures ($T \sim 90$ keV) of this hot plasma in the core the PLS instrument, which measures ions with energy-per-charge (E/Q) below 6 kV, would not be able to detect it. The LECP instrument with its large geometrical factor and higher energy coverage $E > 30$ keV was able to detect this hot plasma.

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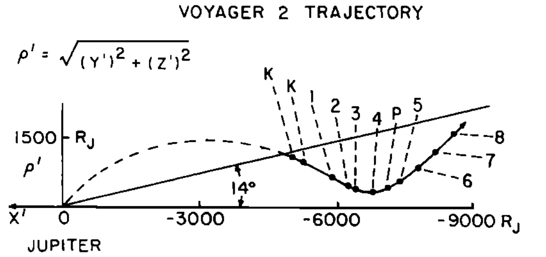

Fig. 1. Voyager 2 trajectory in a Jupiter-centered cylindrical coordinate system wtih the $-x'$ axis aligned along the aberrated position of the tail axis [from *Goldstein et al.*, 1985].

2. OBSERVATIONS

2.1. *Overview*

In Figure 1 [from *Goldstein et al.*, 1985] we show a plot of the Voyager 2 trajectory in a Jupiter-centered coordinate system with the $-x'$ axis oriented along the mean aberrated position of the Jovian tail. This figure shows where 10 tail sightings were observed, i.e., between day 310 of 1980 and day 230 of 1981, when the spacecraft was within 14° of the aberrated tail axis. As discussed by *Kurth et al.* [1982] and *Lepping et al.* [1983*a*], these tail events occurred when the solar wind ram pressure dropped to lower than average levels (rarefaction regions). Thus the Jovian tail was observed when it was allowed to expand axially and engulf the Voyager 2 spacecraft. Axial radial dimensions of the distant tail are estimated to vary approximately between $\gtrsim$0.6 AU and 1.6 AU except during major tearing away of the tail [*Lepping et al.*, 1983*a*]. Of the 10 events shown in Figure 1 we have made comparisons between the PLS, MAG, and LECP data sets in only three of the major tail events, 2, 3, and 5, for which events 2 and 3 gave the clearest evidence for a hot plasma component within the core regions. Event 3, which came within 400 R_J of the mean aberrated position of the tail axis, was the longest and most spectacular for the PLS instrument in that it lasted for nearly 2 weeks and had numerous core encounters within which PLS densities were less than 10^{-3} cm^{-3}. It is this event that we present in this paper as evidence for a hot plasma component within the core regions of the distant tail. In event 5 there is evidence for enhancement, of LECP fluxes within the sole core event of that sighting, but it is not as convincing.

Figure 2 is a plot of the hot ion pressure P_H observed by the LECP instrument, the ion density n_e observed by the PLS instrument ($n_e = n_p + 2n_\alpha$, n_p is proton density, and n_α is alpha density), the magnetic field strength B, and the magnetic field orientation β ($\beta = 0°$ for IMF orientation; $\beta = \pm 90°$ for tail orientation) as defined by *Lepping et al.* [1983*a*]. The LECP pressures were based on an assumed composition of protons and oxygen O^{n+} ions; since the LECP instrument cannot distinguish between ions of different charge state (e.g., O^+, O^{++}, etc.), we used the notation O^{n+} for convenience. If this hot plasma is of Jovian origin, then sulfur ions S^{n+}, etc., will also be present. Measurements by the PLS instrument of the thermal plasma at Jupiter indicate the presence of oxygen and sulfur ions of various charge states with a mean mass of 22 amu [*McNutt et al.*, 1981; *Bagenal and Sullivan*, 1981; *Belcher*, 1983]. This thermal plasma is expected to contribute to the magnetospheric wind observed by LECP in the near-Jovian

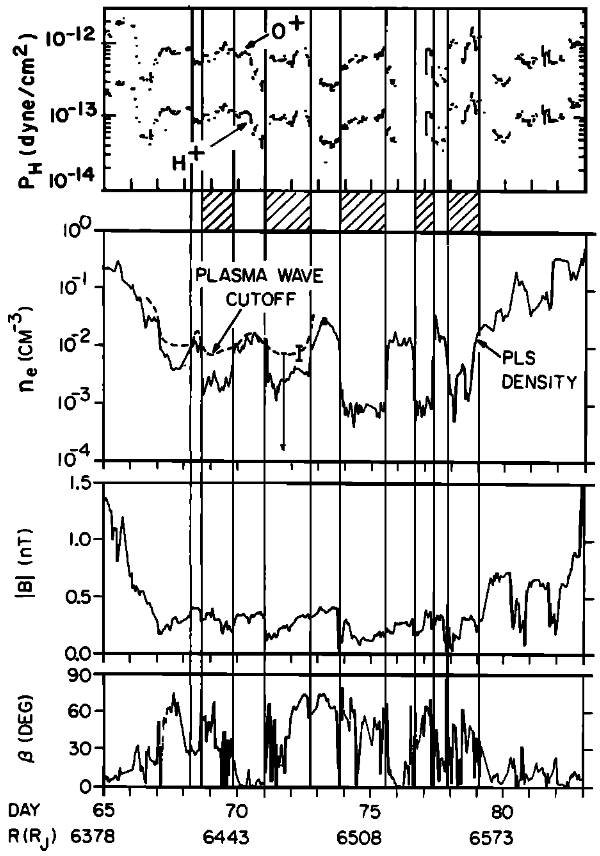

Fig. 2. Voyager 2 parameters for event 3 of Figure 1 plotted versus time from 1981 day 65 to day 83. From top to bottom: the LECP hot ion pressure P_H, PLS ion density n_e, magnetic field strength |**B**|, and the absolute value of the field orientation angle β plotted. See text for details.

tail region [*Krimigis et al.*, 1980, 1981]. As can be seen, the heavier ions give a larger estimate for the ion pressure; if a mean mass of 22 amu is more appropriate, then the quoted pressure will be higher by ~50%. The LECP pressures were estimated only from fluxes above the low-energy cutoff of the instrument E_0 (28 keV for protons; 66 keV for oxygen ions [see *Krimigis et al.*, 1981, 1983] and thus if half the ion pressure resides below E_0, the pressure will be underestimated by a factor of 2. This assumption is based on hot ion observations within the Jovian magnetosphere, where the ion spectra are observed to turn over at the lower LECP channels. A Maxwellian can be fitted to these lower channels, which allow extrapolation below E_0. When this is done, one finds that less than half the ion pressure resides below E_0 [see *Krimigis et al.*, 1981]. But the pressures were computed using data in angular sector 1 (see Figure 3), which measures ion fluxes coming from Jupiter's (solar) direction, and then isotropy was assumed. Since the ion fluxes peak in this angular sector, as shown in section 2.3, the LECP pressures were overestimated by this method by about a factor of 6. Therefore Figure 2 overestimates the total hot ion pressures by about a factor of 3. In Figure 2, no distinction has been made between ram and thermal pressures. That distinction will be discussed in a later section. Data from angular sector 1 were used for estimating the LECP pressures because of the resulting higher count rates, and thus greater signal to noise ratio, and because the flux increases are more dramatic in this angular sector than

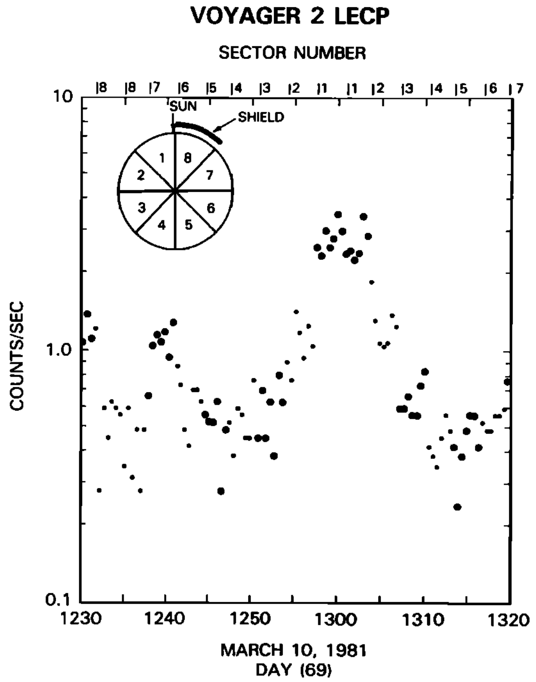

Fig. 3. LECP count rate versus time for ion energy channel PL02 when the Voyager 2 spacecraft was within a core region. Because the LECP instrument scans in time, this plot is also a plot of ion count rate versus angle. The eight angular sectors are defined in the upper left inset, and angle sector number is indicated on the top horizontal axis. Alternating symbols are used to discriminate between data in nearby angular sectors: large dots for odd numbered sectors and small dots for even sectors.

the others (e.g., flow is more beamlike in the core regions). The PLS ion densities were estimated using the method described by *Kurth et al.* [1982]. A similar plot of this data set, without the LECP data, can be found in the paper by *Kurth et al.* [1982], and many of the features in this event are discussed in that paper.

For our purposes in this paper we will concentrate our attention on the relationship between the LECP data and the PLS and MAG data. The most striking feature in Figure 2 is the definite anticorrelation between the LECP ion pressures and the PLS ion densities for many features during the tail event. This anticorrelation is observed even for the brief core events at 0400 and 1500 spacecraft event time (SCET) on day 78. Anticorrelations also occur between the LECP ion pressures and the magnetic field strength B but perhaps are not as striking. Near the end of the tail event, after day 80, when the spacecraft is in the process of reentering the solar wind, there is a clear anticorrelation between n_e and B (contrary to what is observed in the core). Here we may be seeing time stationary structures in the solar wind frame that are in quasi-pressure balance (plasma beta of ~ 1) and that are being convected past the spacecraft. During this later period the LECP data display no clear relationship with the PLS and MAG variations. During the tail part of the event the LECP fluxes display a definite enhancement within the core regions, where the PLS densities are very low ($n_e < 10^{-3}$ cm^{-3}), and the magnetic field strength B tends to be lower. Outside the core regions the reverse is seen. We therefore have convincing evidence for the pressure of a hot plasma component within the core regions as first suggested by *Kurth et al.* [1982], with the implied possibility of pressure balance at core "boundaries."

If one assumes the composition is primarily heavy ions within the core regions, as argued below, and primarily composed of protons outside the core regions, then the hot ion pressure variations become even more dramatic across the core region boundaries. Additionally, with this choice of composition the hot ion pressures within the core regions exceed the hot ion pressure within the solar wind, shown to the extreme left of Figure 2. If the above interpretation holds, then Figure 2 shows a large-scale increase in the hot ion pressure throughout event 3 with abrupt increases due to the core regions. Correspondingly, there is a large-scale decrease in the PLS ion density and the magnetic field strength throughout the tail event with localized minima within the core regions. So on a large scale the observations display the required anticorrelation between LECP and PLS-MAG for the Jovian tail to be in quasi-pressure balance with the solar wind plasma. Overall, the variations in P_H, n_e, B, and β are all consistent with the spacecraft entering the hot plasma sheet of Jupiter's distant magnetotail.

2.2. *Angular Characteristics of the Hot Plasma Fluxes*

In Figure 3 we show the observed ion flux in energy channel PL02 as a function of time for a 50-min interval when the spacecraft was in the core region on day 69. PL02 measures ion fluxes with mean energy of 61 keV for protons and 121 keV for oxygen. Every 25 min 36 s the LECP instrument completes one 360° angular scan in the form of eight angular sectors as shown in the upper left-hand inset [see *Krimigis et al.*, 1977]; it scans from one angular sector to the next every 192 s (and takes about 1 s to move from one sector to the next). The count rate sample time was 24 s, and therefore Figure 3 shows a number of data points within each sector. The scan sequence, shown along the top of Figure 3, is such that the instrument scans from sectors 1 to 8 and then 8 to 1. The inset shows that angular sectors 1 and 8 see ions coming from the solar or Jovian direction, sectors 2, 3, 6, and 7 see ions moving transverse to the spacecraft-Jupiter line, and sectors 4 and 5 see ions moving toward Jupiter. Note that for sector 8 a shield is in front of the detector, and the measured flux in this sector gives an estimate of the background counts that contaminate the measurements made in the other sectors.

The data clearly show an enhancement in ion fluxes coming from the Jovian (and solar) direction which is consistent with a flow of plasma from a Jovian source and aligned along the tail axis. Outside the core regions, ion fluxes are lower in the forward sectors (1, 2, and 7) than observed within the core regions, and the angular variations of the observed flux outside the core regions are characteristically more isotropic. This appearance of isotropy may simply be due to the fact that the signal in the forward sectors dropped to near-background levels. Figure 4 is a plot, which shows the count rate in angular sectors 1, 2, and 5 for all of day 75. The purpose of this plot is to show the angular variation of the fluxes within the core regions, with almost all the observed flux in angular sector 1. As the spacecraft moves outside the core region (1620 SCET), the fluxes in those sectors facing Jupiter decrease, and the observed signal drops down to the noise level of the instrument after 1800 SCET, so that ion fluxes are nearly the same in all angular sectors.

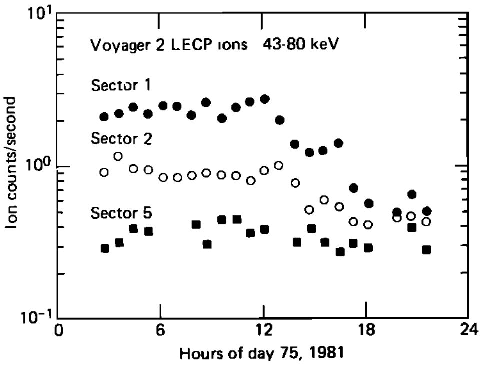

Fig. 4. LECP count rate versus time for PL02 energy channel for angular sectors 1, 2, and 5 for all of day 75.

2.3. *Spectral Characteristics of Hot Plasma Component*

Figures 5 and 6 are log-log plots of the hot ion distribution function measured by the LECP instrument within one of the core regions. The distribution function is plotted versus ion speed after it has been shifted into the proper frame of the plasma moving at velocity **V** (determined by the analysis described below). The plasma composition was assumed to be protons for Figure 5 and oxygen ions for Figure 6. Both spectra represent a time average of ion fluxes within a 4-hour 48-min time interval from 0711 to 1159 SCET on day 74, which was done to improve counting statistics and allow background subtractions to be performed. In each figure, data from angular sectors 1, 3, and 5 are shown. When the data are properly shifted into the proper frame, all the data points collect along a single straight line in the $\log f$ versus log $[(v - V_0)/v_0]$ plot (i.e., $V_0 = V$ for sector 1, $V_0 = 0$ for sector 3, and $V_0 = -V$ for sector 5). The ion flow speed is V, and v_0 is the ion speed at the low-energy cutoff of the LECP instrument $E_0 = \frac{1}{2}mv_0^2$. Therefore the ion spectrum obeys a power law with respect to energy or velocity with the energy power law index $\gamma = 3.54$ for protons and $\gamma = 4.5$ for oxygen ions. For protons the estimated flow speed is $V = 800$ km/s, mean proper frame energy $T_H = 48$ keV, and density $n_H = 2 \times 10^{-7}$ cm^{-3} (for $E > E_0$). For oxygen ions the flow speed is $V = 200$ km/s, $T_H = 87$ keV, and $n_H = 10^{-6}$ cm^{-3}. Because the spectrum is steeper for heavy ions, one can show there is potentially more ion pressure below the instrument's low-energy cutoff E_0. Note that the data in Figure 3 show the signal to be almost all noise in sectors 4 and 5, so that most of the observed signal in sector 5 was background. Therefore the good fit for sector 5 data in Figures 5 and 6 may be fortuitous. Using the estimated n_H and V, the computed ram pressure $\rho_H V^2$ for the hot plasma that lies within the LECP energy range is 2×10^{-15} dyne/cm^2 for protons and 10^{-14} dyne/cm^2 for oxygen ions, more than 3 orders of magnitude below that typically observed in the solar wind. Finally, the above estimates n_H and T_H allow us to estimate P_H, which does not include the ram pressure term. When this is done, we get $P_H \approx 1.3 \times 10^{-14}$ dyne/cm^2 for protons and $P_H \approx 1.3 \times 10^{-13}$ dyne/cm^2 for oxygen ions (again, for the pressure contributions that lie within the LECP energy range). For this same time interval the estimated pressures shown in Figure 2 using only sector 1 data give $P_H = 8 \times 10^{-14}$ for protons and $P_H \approx 7 \times 10^{-13}$ dyne/cm^2 for oxygen ions. Therefore as noted before, the method described in section 2.1 overestimates the portion of P_H within the LECP range by a factor of 6. Then if we assume the same amount of pressure resides below E_0, the P_H shown in Figure 2 overestimates the total thermal pressure by about a factor of 3.

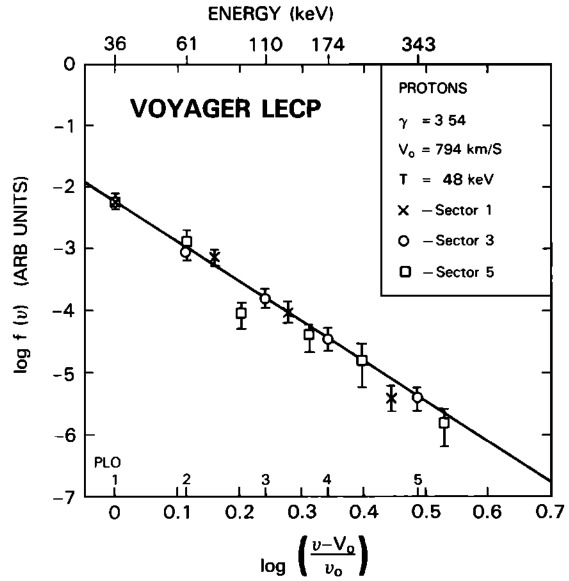

Fig. 5. Log-log plot of hot proton distribution function $f_H(v)$ versus $(v - V_0)/v_0$ such that speeds derived from angular sectors 1, 3, and 5 have been approximately shifted into the proper frame of the plasma, which is moving radially away from Jupiter at speed V_0. The low energy cutoff of the instrument is $E_0 = \frac{1}{2}mv_0^2$. Error bars are uncertainties due to counting statistic errors and do not include any systematic uncertainties attributed to background subtractions, which are severe for sector 5.

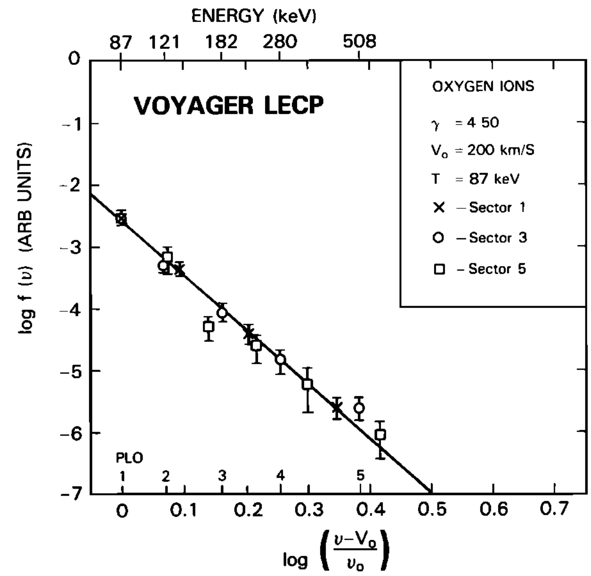

Fig. 6. Same as Figure 5 except assumed composition is oxygen.

2.4. *Pressure Balance Considerations*

Using the approach outlined by *Lepping et al.* [1983*a*], we have the following equation for pressure balance across the core boundaries:

$$\rho_E V_E^2 \sin^2 \alpha_E + \frac{B_E^2}{8\pi} + P_E = \rho_I V_I^2 \sin^2 \alpha_I + \frac{B_I^2}{8\pi} + P_I$$

for which ρ is the mass density, V the plasma flow speed, α the angle of attack the flow makes with respect to the boundary surface, B the magnetic field strength, and P the plasma pressure ($P = P_e + P_i$ where P_e, P_i are the electron and ion pressure, respectively). The subscripts E, I stand for external and internal relative to the core region. For simplicity of argument we will ignore the ram pressure term, which lessens the internal pressure requirements of the hot plasma for pressure balance. If we were to take the boundary crossing time to be day 71 0145 SCET (others at day 67 0000 SCET and day 73 1815 SCET could also be used), the thermal pressure of the solar wind plasma observed by PLS outside the core region is estimated to be $P_E \approx 1.3 \times 10^{-13}$ dyne/cm^2 and the magnetic field pressure $B_E{}^2/8\pi \approx 5 \times 10^{-13}$ dyne/cm^2. Therefore we have a low-β plasma just outside the core regions where the magnetic field pressure dominates. Within the core region the plasma pressure observed by the PLS instrument is undetectable, and the magnetic field pressure has dropped to $B_I{}^2/8\pi = 7.5 \times 10^{-14}$ dyne/cm^2. Excluding LECP data, the pressure differential is $\Delta P = P_E - P_I \approx 5.5 \times 10^{-13}$ dyne/cm^2. If one uses the hot ion pressure shown in Figure 2 for protons, one gets $\Delta P_H/3 \approx 1.67 \times 10^{-14}$ dyne/cm^2 ($\Delta P_H = P_{HI} - P_{HE}$), which is more than an order of magnitude below that required for pressure balance (the factor of 3 in $\Delta P_H/3$ results from our previous estimate that ΔP_H in Figure 2 overestimates the thermal pressure by a factor of 3). Inclusion of the solar wind ram pressure term makes the case for protons even worse. But if one uses $\Delta P_H/3 \approx 2 \times 10^{-13}$ dyne/cm^2 for oxygen ions, quasi-pressure balance becomes possible; this supports the interpretation that the core regions are a permanent feature of the Jovian tail and are not a transient phenomenon.

Similar arguments can be made for some of the other boundary crossing times. For the core regions centered on day 72 0000 SCET and day 74 1500 SCET the major change in magnetic field pressure occurs when the spacecraft enters the core region. Subsequently, there is a general rise in B_I until the exiting boundary crossing time, when there is very little change in $B^2/8\pi$. The gradual rise in B is consistent with an increase in external pressure and an axial compression of the tail. For the boundary crossing beginning at about day 72 1700 SCET the pressure change from PLS and MAG was $\Delta P = 4 \times 10^{-13}$ dyne/cm^2 and from LECP $\Delta P_H/3 \approx 1.67 \times 10^{-14}$ dyne/cm^2 for protons and $\Delta P_H/3 \approx 2.7 \times 10^{-13}$ dyne/cm^2 for oxygen ions. Although the above boundary crossing has a large data gap within it, the pressure differential due to the solar wind plasma alone, $P_E - P_I \sim 1.3 \times 10^{-13}$ dyne/cm^2, can exclude protons as the plasma composition within the core regions, if quasi-pressure balance is to be satisfied. Finally, we note that the plasma beta within the core region with a composition dominated by heavy ions is ~ 1.

3. SUMMARY AND CONCLUSION

Using data from the LECP, PLS, and MAG instruments on the Voyager 2 spacecraft, we have presented observational evidence for the presence of a substantial hot plasma component within the core regions of the Jovian tail, as originally predicted by *Kurth et al.* [1982]. For this paper we have presented data only from event 3, using the numbering system introduced by *Lepping et al.* [1983*a*], but similar evidence for a hot plasma component within the core regions of the other major tail events exists and could also have been given. Event 3 was shown because the evidence from that event was most clearly evident. The observations clearly show an anticorrelation between LECP ion pressure P_H and both PLS density n_e and MAG magnetic field pressure $P_B = B^2/8\pi$. The anticorrelations are such that the LECP pressures are enhanced within the core regions relative to that outside, while the reverse is generally true for n_e and P_B. The magnetic field pressure need not be a minimum within the core regions, although there is always a large-scale decrease in P_B centered on the major tail events. For example, during event 2 there was a rise in B within the core event on day 51 (see Figure 6*a* of *Goldstein et al.* [1985]).

The data in most events show a large-scale increase in the LECP hot ion pressure during the tail event relative to that outside in the solar wind, if protons are assumed to be the ion composition in the regions with solar wind plasma and heavy ions (O^{n+}) are assumed to be the ion composition for the core regions. This hot plasma was found to provide the required pressure within the core regions for pressure balance across the core region boundaries if the composition of this hot plasma within the core regions was dominated by heavy ions. Since some form of quasi-pressure balance must occur if the core regions are to be a permanent feature of the Jovian tail, as observations appear to indicate, then heavy ions must dominate the composition of this hot plasma, which must therefore be of Jovian origin. *Lanzerotti et al.* [1980, 1987] studied pressure balance across plasma sheet crossings of $\sim$40–120 R_J from Jupiter on the nightside using LECP and MAG data. In both studies there was a tendency for a larger fraction of the proton pressure (versus heavy ion pressure) to be needed to supply the required pressure balance but with a tendency for an increase in the fraction of the pressure due to heavy ions (oxygen) to that of protons being needed for plasma sheet crossings as the radial distance from Jupiter increased. For example, at $\sim$80 R_J, 75% of the proton pressure (P_p) and 25% of the oxygen pressure (P_O) were needed to supply the required pressure, while at 120 R_J, 50% P_p and 50% P_O were needed. So we may be seeing evidence for a compositional change with radial distance, such that heavier ions contribute more to the plasma pressure at larger r (*Lanzerotti et al.* [1987] do note that this apparent compositional change could be artifically caused by a change in spectral index γ with r). Then since the magnetospheric wind will form beyond 150 R_J, the ionic composition may be such that almost all the plasma pressure is provided by heavy ions, which appears to be the case in the distant magnetotail, i.e., beyond $\sim$6000 R_J. Furthermore, the thermal plasma measurements in the dayside Jovian magnetosphere by PLS give a mean ion mass of $\approx$22 amu with protons providing only a small fraction of the ion mass [*McNutt et al.*, 1981]. Therefore if, as expected, the thermal plasma makes an important contribution to the magnetospheric wind observed by LECP (ion acceleration assumed to occur), then heavy ions will be expected to dominate the ion composition in the distant tail.

Angle scan plots of the LECP fluxes observed during the tail events show this hot plasma within the core region to be flowing away from Jupiter along the tail axis. Outside the core regions the LECP ion fluxes are lower and appear more isotropic. The energy spectra in Figures 5 and 6 show that this hot plasma obeys a power law when the data have been shifted into the proper frame of the plasma. Flow speeds are estimated to be $V = 800$ km/s for protons and $V = 200$ km/s for oxygen. The energy spectral indices are $\gamma = 3.5$ for protons and $\gamma = 4.5$ for oxygen ions. The mean proper frame energies give $T_H = 48$ keV for protons and $T_H = 87$ keV for oxygen.

Since this hot plasma in the distant tail is apparently of Jovian origin, it is tempting to attribute it to being a remnant of the magnetospheric wind observed by *Krimigis et al.* [1980, 1981]. This wind was observed in Jupiter's magnetotail by the Voyager 2 LECP instrument at distances greater than 150 R_J and near the outbound magnetopause crossing. With the exception of the observation of some highly directed, monoenergetic beams of ions this wind consists generally of convected Maxwellians with power law tails. The angular scans showed that the convection velocities point away from the Jupiter (or sun) direction. Densities were estimated to be $n_H \sim$ 1–3 $\times 10^{-4}$ cm^{-3} assuming protons and 3–10 $\times 10^{-4}$ cm^{-3} assuming oxygen ions. The estimated flow speeds were 300–900 km/s for protons. The thermal energies are of the order of 100 keV/particle. The thickness of the emitting region is of the order of 5 R_J, and it has been hypothesized by *Krimigis et al.* [1981] that the source region extends across the entire magnetotail.

If the distant tail hot plasma is directly associated with the magnetospheric wind, the parameters of one phenomenon ought to be related to the other by means of conservation of mass. The flow velocities within the magnetospheric wind are consistent, to within a factor of 2, with the distant tail flow velocities. Hence the mass conservations condition, ρVA = const, reduces to $n_N t_N L_N = n_F t_F L_F$, where subscripts N and F refer to near and far, n and t refer to density and source region thickness, respectively, and L is essentially the diameter of the tail at the measurement point. Using $n_N = 5 \times 10^{-4}$ cm^{-3}, $t_N = 5\ R_J$, $L_N = 2 \times 170\ R_J$, $n_F = 10^{-6}$ cm^{-3} and using $L_F = 1000\ R_J$ [*Lepping et al.*, [1983*a*], one calculates that $t_F \approx L_F$. In other words, one would predict that the magnetospheric wind essentially fills up the entire distant magnetotail. In hypothesizing a connection between the magnetospheric wind there is clearly no problem with source strength. Observationally, however, the hot plasma in the distant magnetotail may be confined to regions (the core regions) smaller than the full tail area. Then if the magnetospheric wind is the source of the distant magnetotail hot plasma, some plasma must be lost from the tail as the plasma is transported tailward, or the magnetospheric wind source region does not extend across the entire magnetotail [e.g., *Vasyliunas*, 1983]. Overall the data are consistent with the hypothesis that the magnetospheric wind is the source of the distant tail hot plasmas.

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