

LOW FREQUENCY RADIO WAVES AS A DIAGNOSTIC OF THERMAL PLASMA DENSITY IN THE JOVIAN PLASMA SHEET

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Abstract

By using PRA (Planetary Radio Astronomy), PWS (Plasma Wave System) and MAG (Magnetometer) data from Voyager 1, essential features of the nightside Jovian plasma sheet are derived, and the density gradient of the corotating plasma structure in the middle Jovian magnetosphere is calculated. The PRA experiment gives information about the plasma wave polarization. The emission is found to be left-hand polarized when the spacecraft was in the northern magnetic tail lobe, and right-hand in the southern lobe. The PWS experiment enables the determination of a density profile of the Jovian plasma sheet from the knowledge of the low frequency cutoffs observed at 3 frequencies ($f=562$ Hz, $f=1$ kHz, $f=1.78$ kHz). The results are discussed and compared with those obtained from other investigations.

1. Introduction

Nonthermal continuum (NTC) radiation was first observed in the Earth's magnetospheric cavity outside the plasmopause (Gurnett and Shaw, 1973). It is broadband noise whose frequency can extend from the local plasma frequency f_p , as low as 500 Hz, to the magnetosheath plasma frequency, up to 100 kHz. Thus its lower frequency cutoff can be used to determine the local plasma density. NTC at Earth has a maximum in intensity and

occurrence in the morning/prenoon sector (Gurnett, 1975) and is closely associated with electrostatic upper hybrid (ESUH) waves seen near the plasmopause and magnetopause (Jones, 1980). The electromagnetic (EM) radiation resulting from the mode conversion of the ESUH waves is inherently narrowbanded and thus has been designated terrestrial myriametric radiation (TMR). The continuum is created from the frequency smearing by multiple reflection within the magnetospheric cavity of lower frequency TMR.

Nonthermal continuum has also been observed within the magnetospheric cavities of Jupiter (Scarf et al., 1979), Saturn (Kurth et al., 1982), and Uranus (Gurnett et al., 1986). The present investigation concentrates on the emissions observed by the Voyager spacecraft in the lowest frequency channel of the Planetary Radio Astronomy (PRA) experiment (Warwick et al., 1977) and on the plasma wave observations of the Plasma Wave System (PWS) experiment (Scarf and Gurnett, 1977) during the outbound traversal of the Jovian magnetosphere. The observations confirm the existence of very intense continuum radiation trapped within the Jovian magnetospheric cavity.

Two regions within Jupiter's magnetosphere have plasma and upper hybrid frequencies comparable to the observed PRA frequency of 1.2 kHz and density gradients conducive to mode conversion: the magnetopause and the edges of the plasma sheet. In a recent investigation of the Jovian 1.2 kHz NTC radiation, Leblanc et al. (1986) argued that the source of continuum is probably the morning/prenoon magnetopause.

The present work continues the investigation by Leblanc et al. (1986) (hereafter paper 1) on the polarization measurements and on the 1.2 kHz cutoffs which delineate the plasma sheet. In the first part of this paper (Section 2) polarization measurements of Voyager 1 data are given in terms of magnetic latitude of the spacecraft and in dependence of partial or complete traversals of the plasma sheet. We also compare PRA, PWS and MAG data with respect to the plasma disc and we can see that all these data are a good indicator for this plasma structure. In the following part (Section 3) we determine a plasma disc density model from the low frequency cutoffs at the frequencies ($f=0.562$ kHz, $f=1$ kHz, and $f=1.78$ kHz), respectively. We give an estimate of the error inherent in our model and give suggestions for possible improvements. In the last section (4) the variable parameters in the plasma disc model will be discussed.

2. Polarization measurements and plasma sheet traversals

During the inbound and outbound legs of the Voyager trajectories the PRA experiment recorded emissions at 1.2 kHz, but only when the spacecraft was within the magnetospheric cavity. During the outbound trajectories on the nightside, the 1.2 kHz channels observed periodic intensity enhancements which were recorded as far as the magnetopause. Figure 1 shows Voyager 1 (V1) PRA and PWS measurements, in particular spectral density versus time during one Jupiter rotation. The middle panel displays the radio emission intensity measured in the lowest PRA frequency channel, $f=1.2$ kHz, during Jupiter rotation number 1924. As already pointed out in the paper by Leblanc et al. (1986) the intensity periodically increases by about 20 dB above detection threshold. This pattern is followed by plasma wave amplitudes. The top and bottom panels of Figure 1 show the electric field spectral densities at frequencies 1 kHz and 1.78 kHz, respectively. Both

experiment profiles exhibit coinciding enhancements and as already shown in the Figure 3a and 3b of paper 1, the intensity increases occur mainly within defined Jovian longitude ranges.

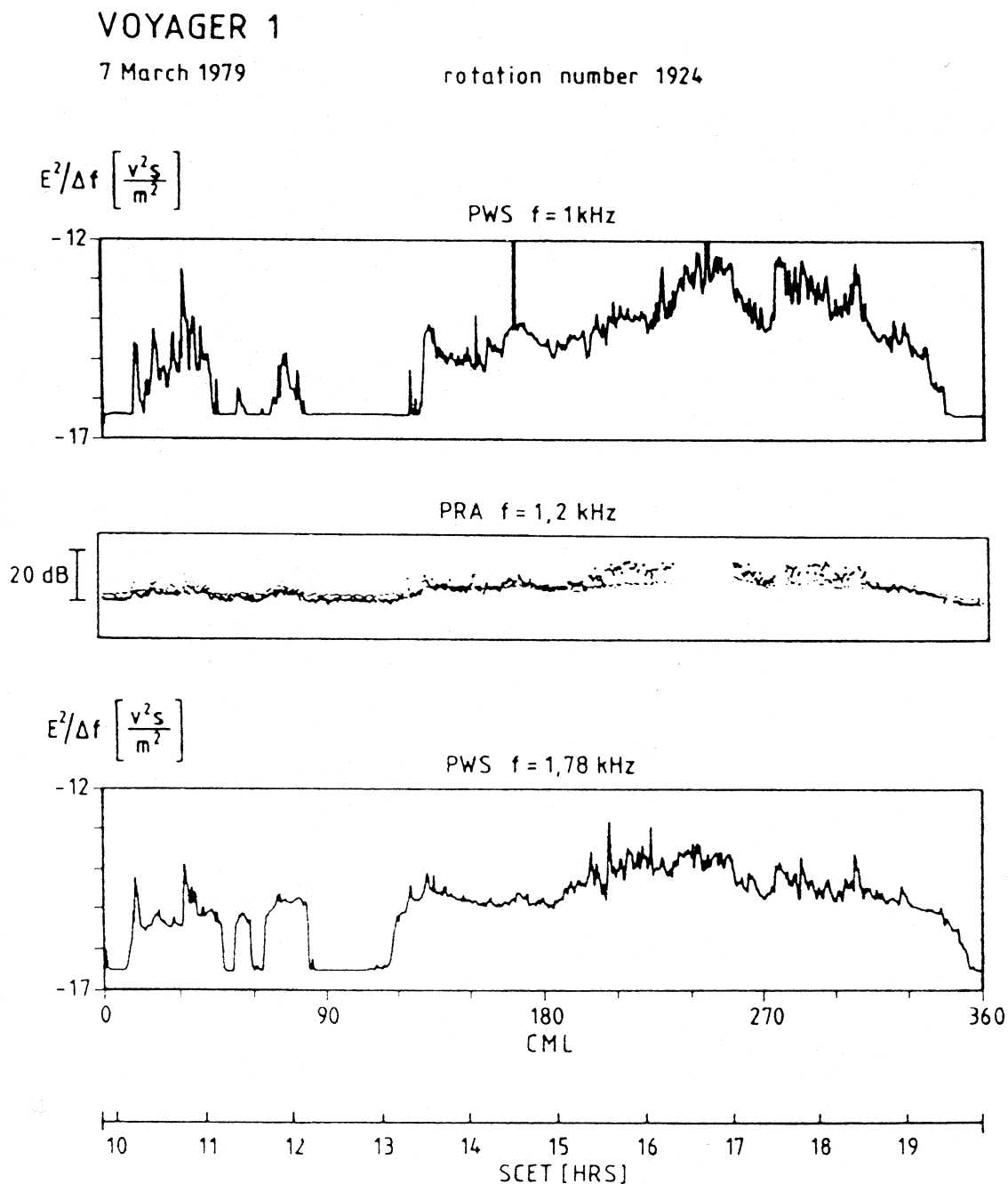


Fig. 1: Voyager 1 measurements of radio waves during one Jupiter rotation. The middle panel shows the PRA 1.2 kHz radio emission as a function of the Central Meridian Longitude (CML) of the spacecraft. The top and bottom panels exhibit the electric field spectral density at neighbouring frequencies.

The occurrence of Nonthermal Continuum Radiation, as observed by V1, is shown in Figure 2 during a number of successive Jovian rotations, starting from rotation number 1921 (March 6, 1979) after V1 – Jupiter closest approach until rotation number 1944 (March 15, 1979) during which the first outbound magnetopause crossing was recorded. The sense of circular polarization of the emission, as well as the plasma sheet traversals, as reported by Ness et al. (1979), are shown. From 16 to 65 Jovian radii (R_J) the emission is seen right hand polarized when the spacecraft is in the magnetic southern tail lobe, and left hand polarized when it was in the magnetic northern tail lobe. A distinct absence of emission occurred near and during the plasma sheet entries and exits. Beyond 65 R_J , the continuum remains left-handed. As will be shown in the next section, this can be understood by knowing that beyond about 50 R_J the spacecraft did not completely cross the plasma disc and remains in the northern hemisphere.

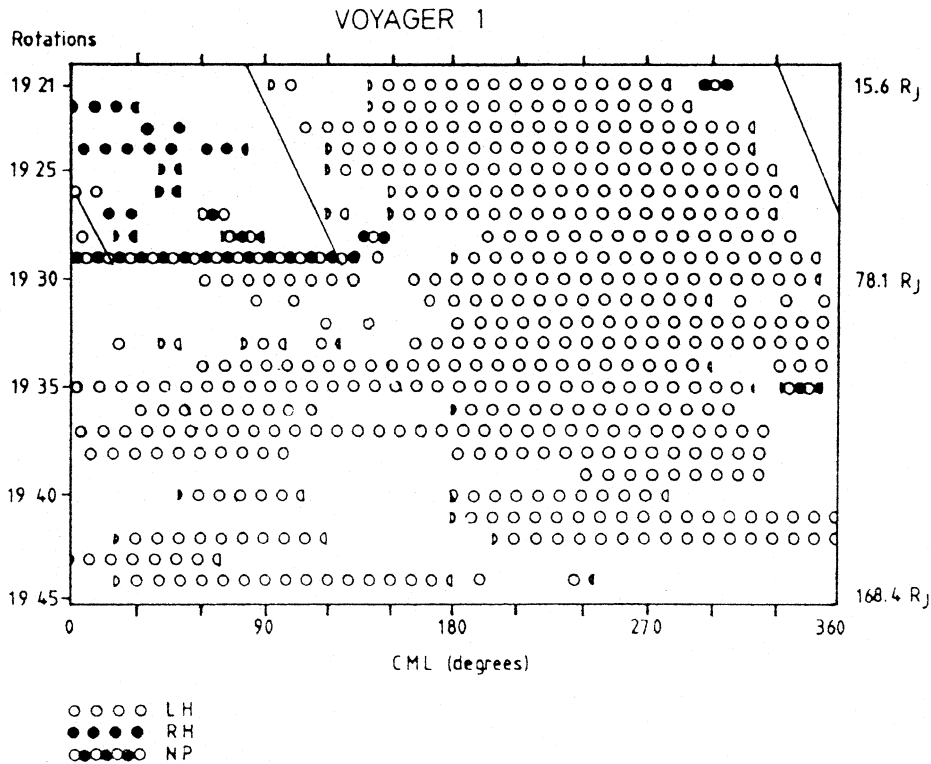


Fig. 2: The occurrence of the 1.2 kHz continuum for V1 as a function of CML during a set of successive Jupiter rotations, as indicated by the respective rotation numbers. The V1 radial distance to Jupiter is shown at right. The solid sloping lines represent the plasma sheet traversals as reported by Ness et al. (1979). Filled circles represent right hand polarization as observed in the southern tail lobe.

Figure 3 shows the relationship between the NTC radiation and magnetic field measurements, and the spacecraft magnetic latitude at $\approx 24 R_J$ during one Jovian rotation. The upper panel represents the intensity of the 1.2 kHz continuum and the polarization indicated by the labels LH for left-hand and RH for right-hand. The middle panel shows the spacecraft magnetic longitude as derived from the Jovian 04 magnetic field model (Acuña and Ness, 1976b) with the location indicated (full line) where LH and RH 1.2 kHz continuum was observed. The lower panel shows the V1 magnetometer data which confirm that

at this radial distance, when V1 was at northern latitudes, the magnetic field is directed away from Jupiter and vice versa at southern latitudes. The plasma sheet traversals are located where the field reverses direction. Figure 3 is a sample of what can be derived from the PRA and MAG measurements (MAG= magnetometer experiment, Behannon et al., 1977) as a characteristic condition throughout a considerable portion of the flapping Jovian plasma sheet and tail lobes. The observations of Jovian 1.2 kHz continuum in the Jovian magnetotail show that when the magnetosphere is relatively quiet as it appears to be during the V1 encounter, the continuum is a good indicator of the position of the plasma sheet.

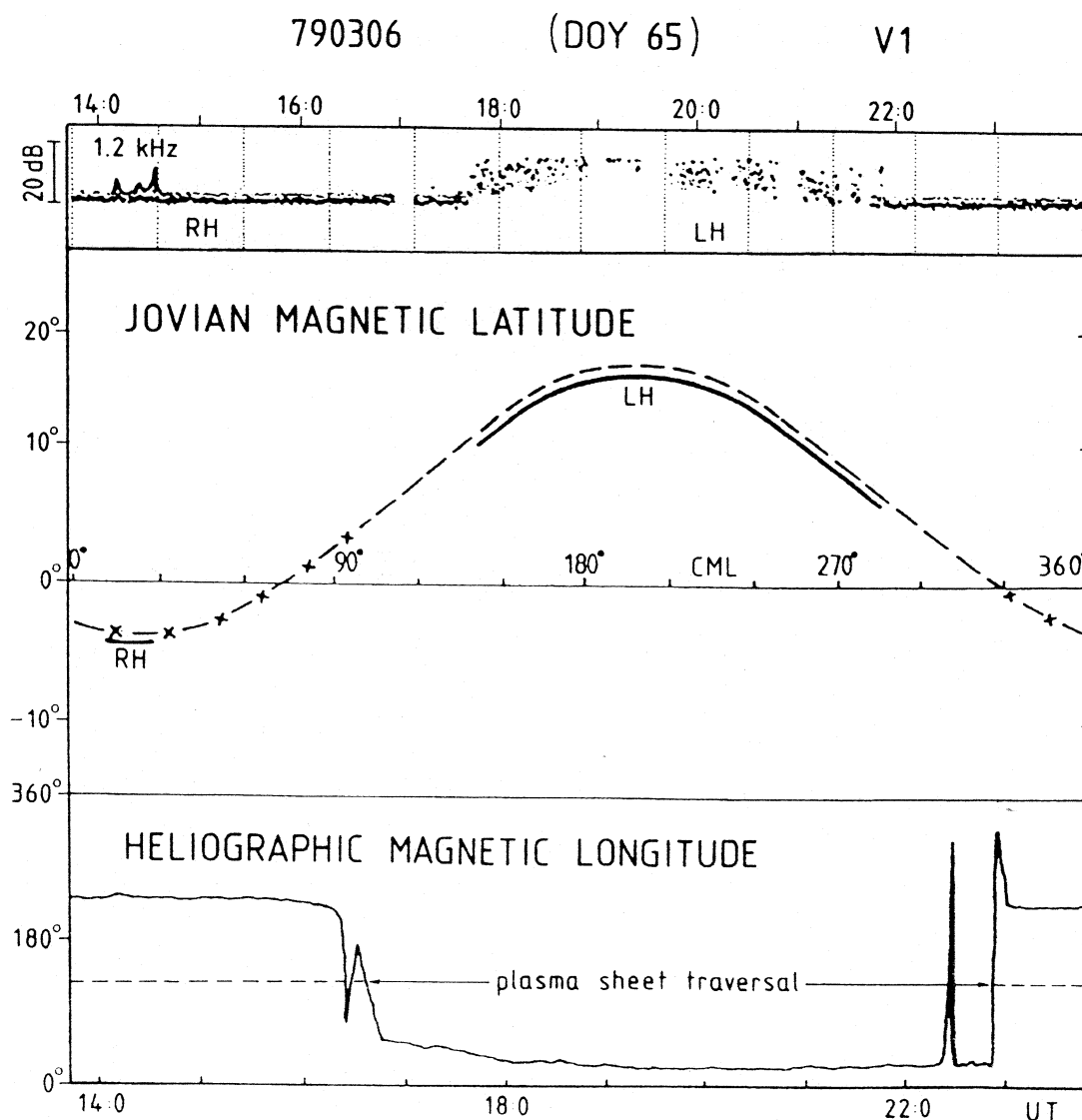


Fig. 3: 1.2 kHz continuum observation by V1 and the local environmental magnetic conditions during a Jovian rotation. The top panel shows a distinct intensity increase of left-hand (LH) polarized emission during times of the spacecraft passage through high Jovian magnetic latitude regions (middle panel). The bottom panel delineates the heliographic magnetic longitude as a clear indicator of the plasma sheet traversal. (From paper 1, Figure 5a)

3. Plasma disc density calculations

The plasma wave experiment, described by Scarf and Gurnett (1977), gives us the unique possibility to determine a density profile of the Jovian magnetoplasma disc by using several low frequency channels. Assuming O-mode propagation such waves cannot propagate if the wave frequency is less than the local plasma frequency (a detailed discussion follows in Section 3.1). Then the cutoffs of the plasma waves in the PWS data are good indicators of the density of the plasma sheet.

The PWS data, especially in the 562 Hz, 1 kHz and 1.78 kHz frequency range, show low frequency cutoffs twice or four times per Jovian rotation. In Figure 4 the PWS data at 562 Hz are displayed from day of year (DOY) 66, 1979, 17:00 hours through DOY 67, 17:00 hours. At the beginning of the period in question, Voyager 1 entered the plasma disc but did not traverse it (position 1 to 2). Then the spacecraft crossed the full plasma disc (position 3 to 4) and appeared at its southern side (position 4 to 5). For these two cases we have two different methods to determine the plasmadisc thickness. Figure 5 shows schematically the geometry of the plasmadisc for this period and the V1 trajectory, which appears in the rotating frame of reference as an outbound spiral. (The points 1–6 in Figure 5 correspond to these in Figure 4.)

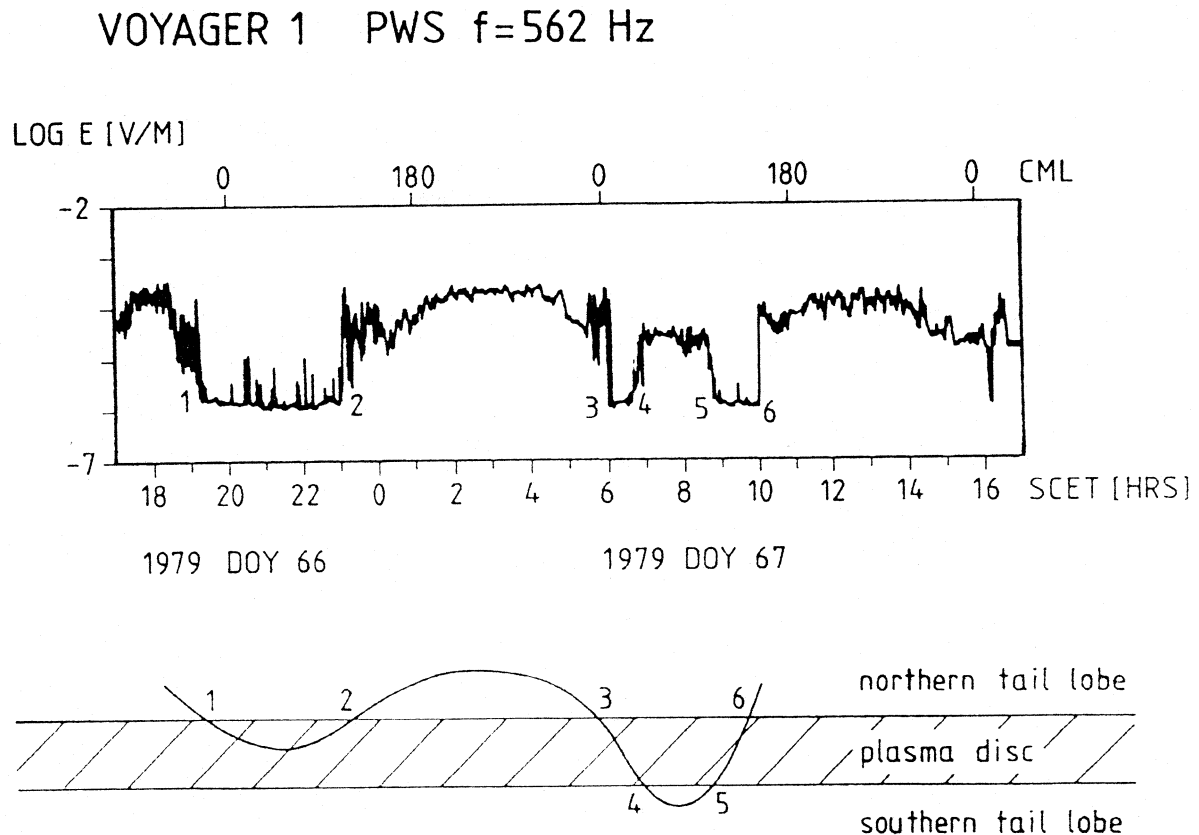


Fig. 4: V1 PWS data ($f=562$ Hz) from DOY 66, 1979, 17:00 hours to DOY 67, 17:00 hours. The points 1 and 2 indicate a plasma sheet entry and exit (northern edge), points 3 through 6 mark a full plasma disc traversal, as demonstrated in a simplified plot (below).

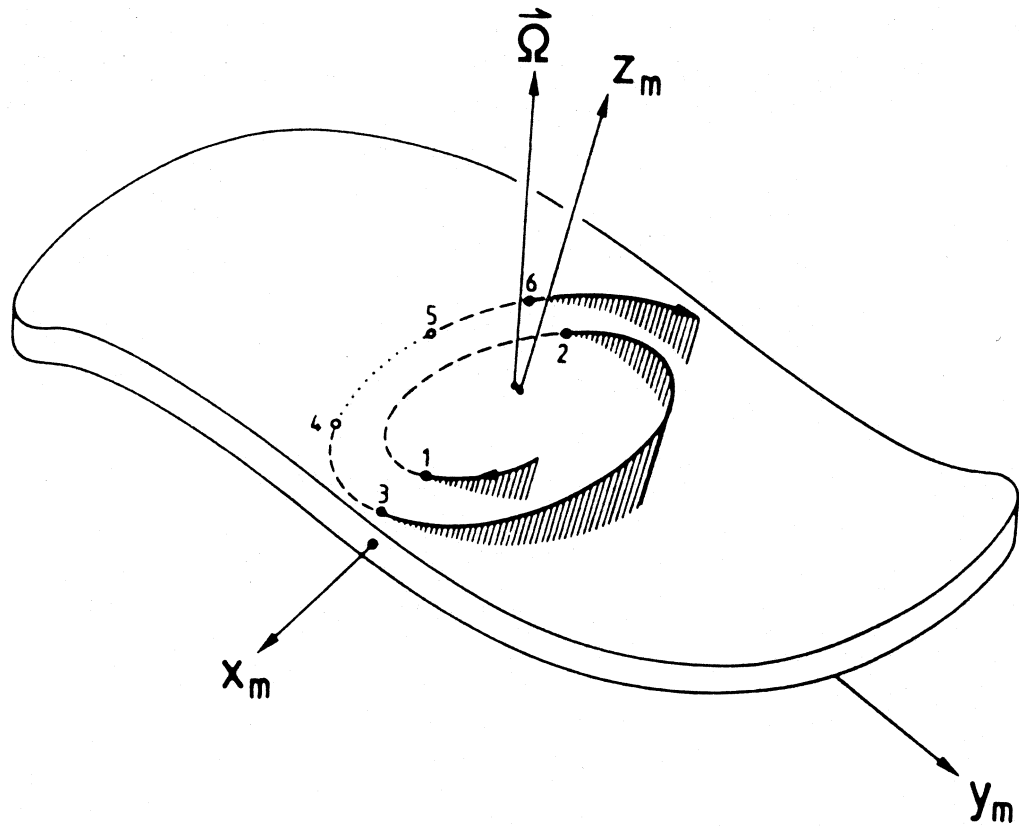


Fig. 5: Schematic geometry of the plasma disc with the V1 trajectory: The plasma disc is rotating with Jupiter and therefore the V1 trajectory after encounter is seen as an outbound spiral. Hatched areas indicate where the spacecraft trajectory lies outside the plasma disc (e. g. below the plasma disc between points 4 and 5).

3.1 Plasma disc crossings

We have made the hypothesis that the observed cutoffs are due to O-mode cutoffs of the plasma waves at the plasma frequency. In a recent paper by Kennel et al. (1987), they state that when the Z-mode band is observable separate from the continuum radiation, the polarization of the continuum emission is R-X, but the times when the Z-mode band is not distinct from the continuum, the polarization is at least partially L-O. We compared our data with Figure 12 in the paper of Kennel et al. (1987), during one plasma disc crossing, and we have found that the Z-mode (562 Hz), but also the R-X mode (1 kHz) occurred. The cutoff frequency of the X-mode occurs at $f_r = f_c/2 + \sqrt{f_c^2/4 + f_p^2}$, which is above the plasma frequency f_p , but in the middle and outer magnetosphere ($r > 40 R_J$) where the cyclotron frequency $f_c \ll f_p$, the difference between the two frequencies f_r and f_p , is quite small.

Throughout this investigation we assumed O-mode propagation. The error using this assumption decreases as the distance from Jupiter increases. Further uncertainties in the results at about $25 R_J$ from Jupiter might also arise from the presence of $(n+1/2)$ odd half harmonic electron plasma waves located at the Jovian magnetic equator (Scarf et al., 1979).

Therefore, the calculations of the plasma disc density profiles are mainly valid for distances larger than $30 R_J$ for the frequencies 1 kHz and 1.78 kHz, and beyond $40 R_J$ for $f=562$ Hz. As mentioned above, the difference between f_p and f_r is increasing with decreasing radial distance, but, as can be shown in subsequent calculations, this difference causes an uncertainty in the sheet thickness of less than $1 R_J$ for the sheet with $f_p > 562$ Hz at regions of about 25 Jovian radii (with the assumption for this region that the cyclotron frequency is of the same order of magnitude as the plasma frequency at the edges of the plasma disc).

We have considered the plasma disc crossings from $25 R_J$ to $80 R_J$ at 3 frequencies. We distinguish two cases: the first, when the spacecraft traverses the plasma sheet only partially, and the second, when it traverses the plasma sheet completely (discussion in Section 3.4).

3.2 Hinge point position

The position of the so-called hinge point is the intersection of the magnetic equator plane and the solar wind direction (denoted by HP in Figure 6). In general we can assume two forces acting on the plasma disc, namely the solar wind pressure and centrifugal forces (Goertz, 1981). These two effects are normally not acting in the same plane but the angular difference (angle between the rotation plane and orbital plane) is very small ($< 3^\circ$). During quiet solar wind conditions an average hinge point position at $60 R_J$ can be assumed (Goertz, 1981).

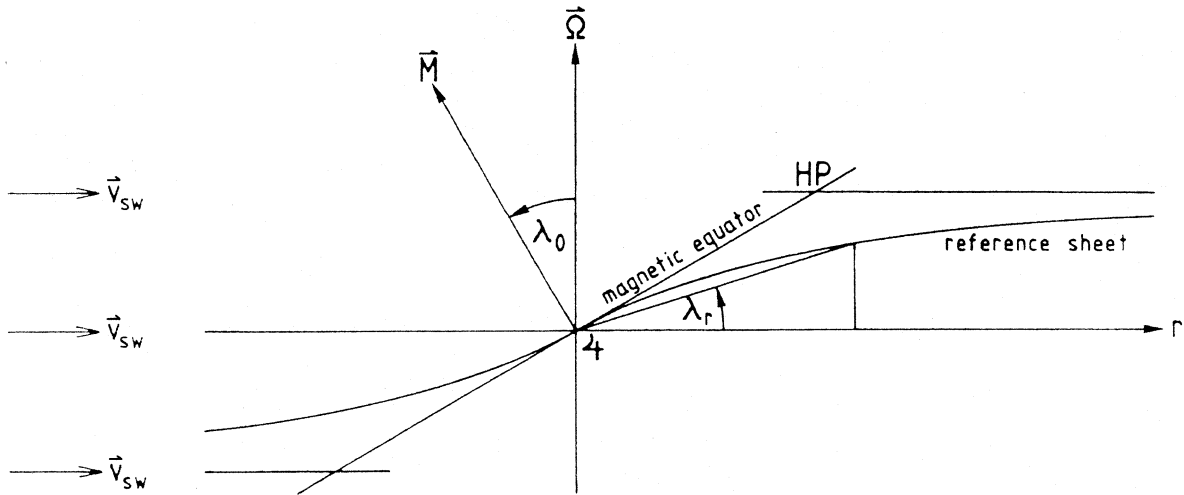


Fig. 6: Noon-midnight meridian cross-section through the inner Jovian magnetosphere at a given CMLM (defined in text) for the nightside. $\vec{\Omega}$ denotes the rotation axis, \vec{M} the magnetic axis, and HP is the hinge point. The direction of the solar wind is indicated by the solar wind velocity \vec{v}_{sw} . The reference sheet is displayed as $y=\tanh(R)$ where R is a function of the hinge point position (see text Equation 2).

Although we investigated the Voyager 2 solar wind data measured during the Voyager 1 Jupiter flyby we could not give a sufficiently accurate estimation of the variation of the hinge point (HP) in the Jovian magnetosphere. As Voyager 1 was at an outbound distance of $40 - 50 R_J$, the solar wind pressure increased and the hinge point consequently moved in. Using the V2 solar wind data during the V1 encounter and a simple pressure equilibrium model for the Jovian magnetopause, we determined a hinge point at a tailward position of about $40 R_J$ for this particular period of time.

Regarding the PWS data at the frequencies $f=562$ Hz and $f=1$ kHz, we could see that Voyager 1 did not fully traverse the plasma disc within the range $40-50 R_J$. So only for the distances $40 R_J < r < 50 R_J$ we used a hinge point position of $40 R_J$ in our calculation of the plasma disc density profile.

3.3 Reference sheet

The plasma disc is a co-rotating plasma structure in the inner Jovian magnetosphere, which is specifically formed by external forces. Close to the rotation axis the plasma is mainly structured by the strong magnetic field and therefore follows the magnetic equator, but with increasing distance the centrifugal forces start dominating, which leads to a bending of the plasma disc in the direction normal to the rotation axis. Due to the small angle between the rotation plane and the orbital plane of Jupiter ($< 3^\circ$) this direction (normal to the rotation axis) almost coincides with the direction of the impinging solar wind.

Figure 6 shows a noon-midnight meridional cross section of the inner Jovian magnetosphere with the rotation axis $\vec{\Omega}$ perpendicular to the onstreaming solar wind \vec{v}_{sw} . (In our model the small angle of $< 3^\circ$, as mentioned above, is neglected.) The figure pinpoints the situation when the magnetic axis \vec{M} lies in the noon-midnight plane and is tilted by $\lambda_0 = 9.8^\circ$ with respect to $\vec{\Omega}$. As pointed out in Section 3.2 the hinge point HP is located at the intersection of the magnetic equator plane with the solar wind direction, at a distance where the magnetic and centrifugal forces change in dominance.

In order to describe mathematically this three-dimensional plasma disc we introduce a so-called “reference sheet”, a structure which azimuthally is defined by a sine-function and in the radial direction by a tanh-function (Behannon et al., 1981). Then the thickness of the plasma sheet will be determined by calculating the distance between the plasma sheet entry/exit point of the spacecraft and the reference sheet.

In the radial direction the reference sheet is approximated by a tanh-function. In order to fit our assumption, this function has an inclination λ_0 through the origin of our coordinate system (center of Jupiter). Therefore, the following can be derived:

$$\tan \lambda_r = \tan \lambda_0 \frac{y(R)}{R} \quad (1)$$

The function $y(R) = \tanh(R)$ and R is the spacecraft–Jupiter distance normalized to the hinge point position (R_h):

$$R = \frac{r}{R_h} \quad (2)$$

Any position on the reference sheet in azimuthal direction then has a declination given by $\tan(\lambda_r)$ multiplied by a sine–function:

$$\tan \lambda_S = \tan \lambda_r \cdot \sin \left(\frac{\pi}{2} + CML - CMLM \right) \quad (3)$$

(λ_S denotes the Jovigraphic declination of a point of the reference sheet at a given distance r and Central Meridian Longitude (CML), and CMLM is the CML of the point of the plasma disc’s highest declination at a given radial distance.)

Since λ_r , λ_S and λ_0 are small angles we can write for the Equations (1) and (3):

$$\lambda_r = \lambda_0 \frac{\tanh(R)}{R} \quad (4)$$

$$\lambda_S = \lambda_r \cdot \sin \left(\frac{\pi}{2} + CML - CMLM \right) \quad (5)$$

With these equations any point of the reference sheet has a defined position and therefore this reference sheet can be used in order to determine a plasma disc density profile, as shown in the subsequent part.

3.4 Calculation of the plasma disc density profile

Analysing the spacecraft traversals of the plasma sheet there are two different cases to distinguish regarding the crossing geometry:

a) Voyager traverses the plasma sheet only partially and enters from the northern side into the plasma sheet (points 1 and 2 in Figure 4). We assume that the spacecraft motion from a plasma disc entry to a plasma disc exit is very small compared to its radial distance from the planet. These two points (northern entry, northern exit) are taken in order to calculate the CML of the point of the highest declination (CMLM) of the plasma disc in Jovigraphic coordinates for the actual radial distance. The longitude CMLM changes rotation by rotation and it can be seen that CMLM is slightly increasing with increasing radial distance. This is also demonstrated in Figure 2 where the solid lines, which delineate the positions of the entries in and exits out of the plasma sheet, slightly tend to higher CML with increasing radial distance. This means that the outer portion of the plasma disc lags the inner portion. Since we have only two crossing points, the reference sheet is taken to be symmetrically placed within the plasma disc. Taking into account a certain hinge point position (see Section 3.2), we can determine the distances between the plasma sheet entry/exit points of Voyager and the reference sheet from the position of the cutoffs of the

Jovian PWS data for each frequency. These cutoff positions can be derived in Jovigraphic coordinates from the data of the spacecraft trajectory and from the calculated position of the reference sheet. The distances between the reference sheet and the respective plasma sheet entry and exit points are not independent. Therefore we have to take the average of these distances to be the half characteristic thickness of the plasma disc at this radial distance from the planet.

b) Voyager traverses the plasma sheet completely, which results in four crossings of specific isodensity contour lines within one rotation period (Figure 4, points 3 through 6). In this case, these four points (northern entry, southern exit, southern entry, northern exit) were taken to determine the characteristic plasma sheet thickness for the distance averaged from these four points. At a given distance r , the CML of the point of the plasma disc's highest declination is calculated as described under a). We did not include the points of the southern plasma disc crossings, because as one can easily see from the geometry of the spacecraft position and the plasma disc, the angle between the spacecraft trajectory and the plasma disc surface at these southern points is very small (grazing crossings). Therefore, a little flapping of the plasma disc (caused by different solar wind conditions) might dramatically change the CML of the crossing points. This effect is smaller at the northern crossing points (northern declination of the spacecraft). In case b), the reference sheet does not need to be the symmetrical sheet. Now we can determine the distances from the crossing points to the reference sheet in the same way as discussed under a). These four points are also not independent, because the two northern points are taken to determine the CML of the plasma disc's highest declination (CMLM) and because the reference sheet does not need to be the symmetrical sheet.

Taking magnetic field data into account the position of the reference sheet could be determined and consequently the first two points would be independent from the second two. This would lead to more values and therefore would be more accurate. Investigations along these lines are under way.

The essential structure of the plasma disc, as known from observations, is mathematically approximated by a tanh-function, which of course leads to uncertainties. Especially at larger distances ($r > 60 R_J$) the error exceeds a few Jovian radii. Therefore we do not use a symmetrical sheet, but have introduced a reference sheet (method b) in order to minimize the error. On the other hand, there is also the problem of the hinge point variation in the Jovian magnetosphere caused by changing solar wind conditions. Only by the exact knowledge of the hinge point position we are able to determine any mathematical sheet in sufficient accuracy (see Equation 2).

3.5 Results

Figure 7 shows the plasma disc thickness, corresponding to the 3 frequencies studied, versus spacecraft distance from Jupiter. Crosses indicate the results obtained by method (a) and circles are derived from (b). Out of a total of 21 values obtained from the plasma disc crossings only one crossing event at about $r \sim 70 R_J$ (with $f=562$ Hz) was not considered because the calculated plasma disc thickness was $\sim 10 R_J$. In this particular case we were forced to take method (a) (assumption for the disc to be mathematically described by a symmetrical sheet). Two points at a distance of $r = 60 R_J$ are denoted as “not clear” (n. c.) which means that we have not found a correspondence in the magnetic field reversal (out of the MAG data) and the wave cutoff occurrence (of the PWS data).

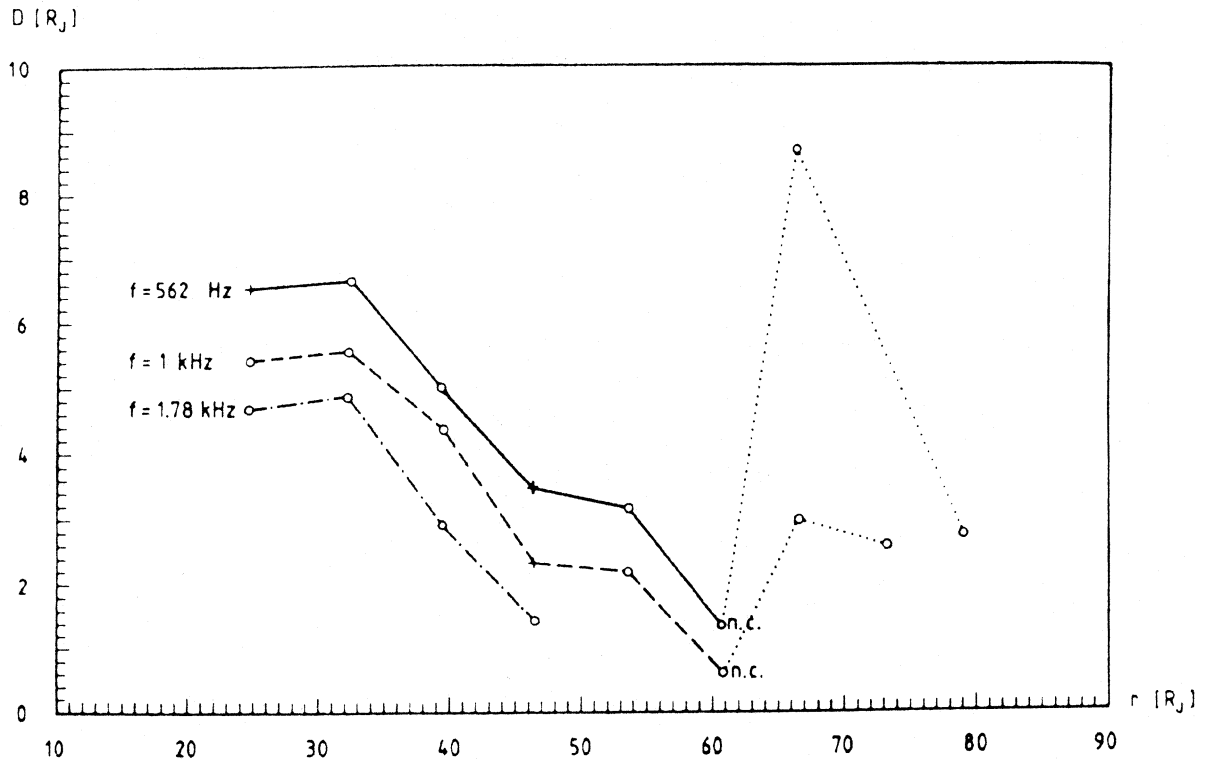


Fig. 7: Plasma disc thickness D as a function of R_J . The different lines indicate different density contours: full line with $N \geq 3.92 \cdot 10^{-3} \text{ cm}^{-3}$ (derived from $f_p \approx 562$ Hz), dashed line with $N \geq 1.24 \cdot 10^{-2} \text{ cm}^{-3}$ (from $f_p \approx 1$ kHz), and dashed/dotted line with $N \geq 3.94 \cdot 10^{-2} \text{ cm}^{-3}$ (from $f_p \approx 1.78$ kHz). The dotted line indicates calculations of the plasma disc thickness beyond $r=61 R_J$ (n. c. denotes “not clear”).

It can be seen from Figure 7 that the disc thickness is decreasing with increasing radial distance, which is due to the natural dilution of plasma in radial distance. On the other hand, as found by V1 during the traversal of the region of about $60 R_J < r < 80 R_J$, the disc thickness with a plasma density of $N > 3.92 \cdot 10^{-3} \text{cm}^{-3}$ (with plasma frequencies higher than 562 Hz) increased and might possibly have extended to 10 Jovian radii.

This feature certainly is of temporal nature and likely not a stable one. Therefore in Figure 7 we have introduced a dotted line for the isodensity contours beyond $r=61 R_J$. In Table 1 we give the average thickness for the respective frequencies 562 Hz and 1 kHz, 1.78 kHz and the deviation from the average. It should be noted that the average thickness for $f = 1.78 \text{ kHz}$ exceeds that of 1 kHz because for $f = 1 \text{ kHz}$ the respective isodensity contour extends to $73 R_J$ whereas for $f = 1.78 \text{ kHz}$ the extension of the isodensity contour is limited at $46 R_J$.

Our results are in good agreement with the plasma disc thickness of $D=4.2 R_J$ (over a range of 30 to $80 R_J$) obtained by Barbosa et al. (1979). With the exception of one point at $\sim 70 R_J$ (562 Hz), we can observe a trend to a lower plasma disc thickness with increasing radial distance. This effect was first mentioned by Barbosa et al. (1979) and Gurnett et al. (1980).

We have to be cautious in taking the values of Table 1 as constants. These results are typical values of the disc thickness during the V1 encounter and may certainly differ from those obtained by V2. Corresponding studies are in progress.

Table 1

	frequency (kHz)		
	0.562	1	1.78
minimum plasma-sheet density (10^{-3}cm^{-3})	3.9	12.4	39.4
average thickness (R_J)	4.64	3.22	3.48
deviation from average (R_J)	2.41	1.69	1.62

Table 1: Average plasma sheet thickness for $f_p = 562 \text{ Hz}$, $f_p = 1 \text{ kHz}$ and $f_p = 1.78 \text{ kHz}$. The minimum plasma densities for the Jovian magnetospheric region are also given for our analyzed PWS frequencies.

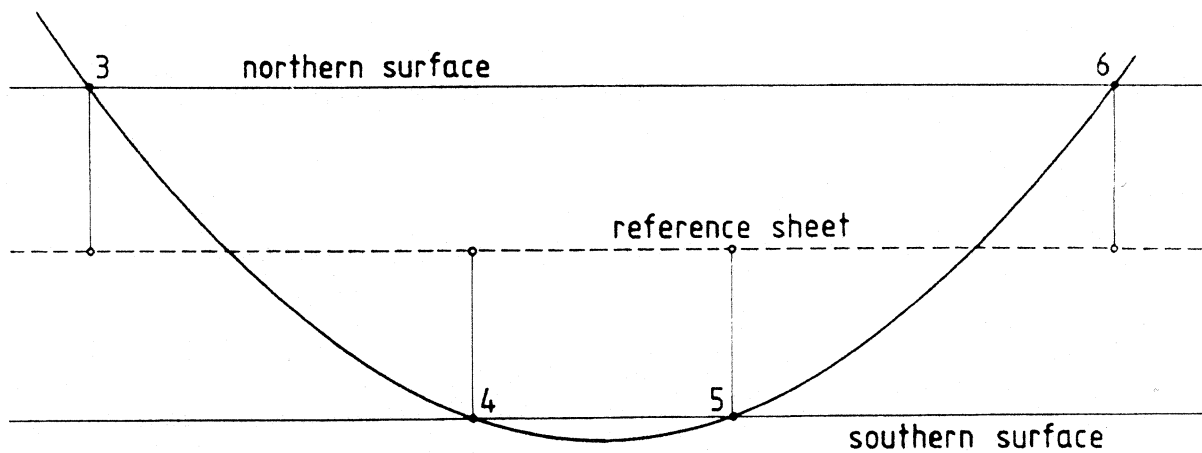


Fig. 8a: The plasma disc as seen edgewise. In this case, the reference sheet completely follows the plasma disc and is also the symmetrical sheet. (If this is the case in reality, no geometrical error would arise in calculating the plasma disc thickness.) The points 3 – 6 correspond to those in Figures 4 and 5.

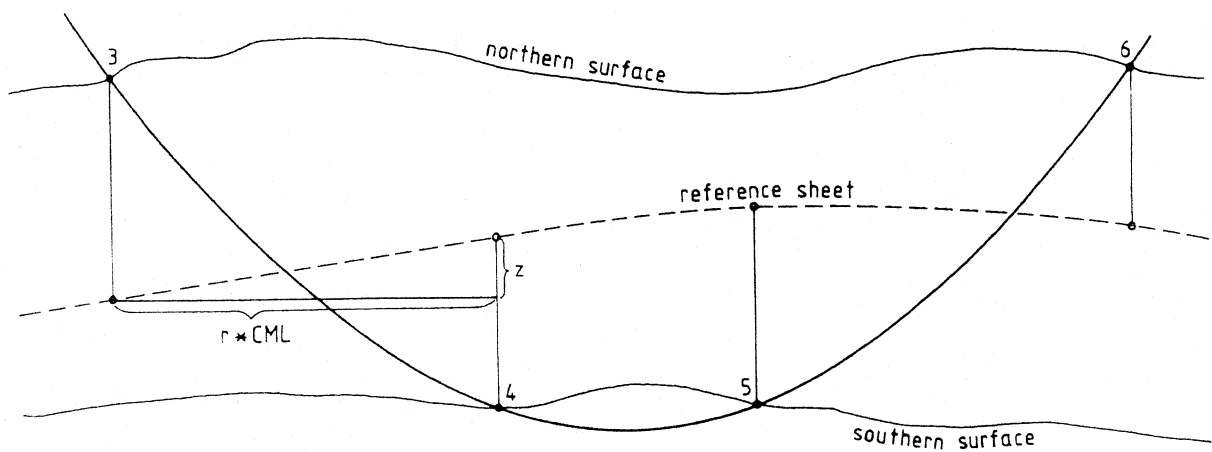


Fig. 8b: Same as Figure 8a, but now the reference sheet does not run parallel to the plasma disc surfaces and is therefore no longer the sheet of symmetry. This configuration certainly represents more closely the real situation.

4. Variable parameters in the plasma disc model

4.1 *Departure from the symmetrical sheet*

In Figure 8a is shown a surface symmetrically placed within the plasma sheet, where no error in the calculation of the sheet thickness arises. In Figure 8b, a more likely real configuration is also displayed. The deviation $k=dz/d(\text{CML})$ is no longer zero and we can calculate k from the reference sheet distances of two complete and subsequent plasma sheet traversals, each consisting of two entries and exits (see points 3 to 6 in Figure 4). This procedure can be performed rotation after rotation. Typical k values for $r < 60 R_J$ are: $1.2 R_J/(2\pi) > k > 0.5 R_J/(2\pi)$. Assuming shorter fluctuations of k of this order and taking into account that the difference in CML between 2 crossing points (northern entry – southern exit or southern entry – northern exit) is of the order of $\pi/2$ (Figure 4), the characteristic geometrical error $E = 0.3 R_J > E > 0.13 R_J$. The difference between the smallest distances between the reference sheet and the crossing points (in the direction perpendicular to the reference sheet) and those indicated in Figure 8b are negligible. As we have already discussed in Section 3, the outer portions of the plasma sheet lag the inner portions and therefore the disc seems not to be symmetrical in the azimuthal direction. This effect is very small and since the spacecraft motion during one rotation is small versus the distance to Jupiter, this effect is also negligible.

4.2 *External influences*

Sometimes the plasma disc thickness shows a highly fluctuating behavior for which we conclude that the structures of the plasma disc are highly dependent on external influences. How external influences exactly act on the plasma disc is not known yet and therefore more investigations on this subject are necessary to determine a model of the plasma disc, which depends on external forces. Further investigation in the magnetic field data would also lead to a more accurate determination of the reference sheet, since the traversals by the spacecraft are clearly indicated by a directional change of the magnetic field. An improvement is aimed at the determination of the plasma disc and sheet density gradient by taking into account the variations of these plasma structures by external forces, i.e. the variable solar wind conditions.

Conclusion

A number of investigations have already been performed on the electron density profile within the Jovian magnetosphere (Gurnett et al., 1980, 1981b) and plasma disc models have been developed (Carbary, 1980; Kivelson et al., 1978); an estimate of the disc thickness is given by Barbosa et al. (1979). They calculated the plasma disc thickness from the time the spacecraft spent in the plasma disc for each rotation. As mentioned above, our results agree very well with the average disc thickness of their investigation, but additionally we are able to provide an information about the isodensity contours of the plasma sheet.

Everyone seems to agree that the plasma disc in the Jovian magnetosphere is not a stable structure and that the influences on the plasma sheet are so complicated that one might

expect to get results with deviations which are not small. We can also show that the disc thickness is decreasing with increasing radial distance.

We introduced a reference sheet in our model because the deviation in the results becomes smaller but, on the other hand, we can obtain only a few characteristic plasma disc thickness values from this model. In fact we found that the error of these results is small and certainly does not exceed one Jovian radius in average thickness.

The main emphasis will be laid on the V2 data and comparable studies will be performed in the near future. If one understands exactly how external forces act on the structure of the plasma disc (e.g. on the variation of the hinge point), more accurate results could be obtained from our model. The present studies clearly show the close connection between plasma structures, such as the plasma disc, and the behavior of radio waves in a magnetic plasma, and will undoubtedly lead to a deeper understanding of the phenomena in the Jovian magnetosphere.