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Periodic Amplitude Variations in Jovian Continuum Radiation

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An analysis of periodic variations in the amplitude of continuum radiation near 3 kHz trapped in the Jovian magnetosphere shows structure with periods near both 5 and 10 hours. Contrary to a plausible initial idea, the continuum amplitudes are not organized by the position of the observer relative to the dense plasma sheet. Instead, there seem to be preferred orientations of system III longitude with respect to the direction to the sun which account for the peaks. This implies a clocklike modulation of the continuum radiation intensity as opposed to a searchlight effect. The importance of the dipole longitude–solar wind alignment to the amplitude of the continuum radiation implies that the source region of the radiation is near the magnetopause and may indirectly tie the generation of the radio waves to the clocklike modulation of energetic electron fluxes from Jupiter.

1. INTRODUCTION

The dominant feature in the radio spectrum of Jupiter below 100 kHz is the trapped continuum radiation [*Scarf et al.*, 1979; *Gurnett et al.*, 1979, 1980]. The spectrum is most intense at frequencies below about 5 kHz, the typical solar wind plasma frequency in the vicinity of Jupiter. Below about 5 kHz the radiation is trapped within the density cavity formed by the Jovian magnetopause and the high-density regions in the inner magnetosphere. In the low-density lobes of the Jovian magnetotail the continuum spectrum can extend below a few hundred hertz. Since the spectrum follows an approximate f^{-4} law, observed power fluxes at the lower frequencies can exceed 10^{-12} W m^{-2} Hz^{-1}.

Figure 1 shows the electric field spectral density as a function of time for five of the Voyager 1 plasma wave receiver spectrum analyzer channels for a 10-day interval beginning on day 65, 1979. The solid black areas represent 16-min average values. The averages allow one to see long period amplitude variations as a function of time. Some of the earliest studies of terrestrial continuum radiation [*Gurnett and Shaw*, 1973; *Gurnett*, 1975] implied the emission was generally characterized by smoothly varying spectra and little temporal structure. More recent studies [e.g., *Kurth et al.*, 1981], using improved instrumentation, demonstrated the narrowband nature of the continuum spectrum. *Gurnett et al.* [1981*a*, 1983] showed the narrowband nature of the emission at both Saturn and Jupiter. Little has been mentioned in the literature about temporal variations in amplitudes, although *Scarf et al.* [1981] observed 10-hour periodicities in the amplitude of continuum radiation trapped in Jupiter's distant magnetotail, some 6200 R_J downstream from the planet.

It is the purpose of this paper to discuss the quasi-periodic variations evident in the continuum radiation observations shown in Figure 1. An understanding of the variations will lead to a more thorough understanding of the source of the emissions as well as further insight into the various mechanisms which are operative in the Jovian magnetosphere. The observations presented are from the Voyager 1 and 2 plasma wave receivers, which are described by *Scarf and Gurnett* [1977].

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2. PERIODIC VARIATIONS OF CONTINUUM RADIATION AMPLITUDES

The continuum radiation observations in Figure 1 are from the 562-Hz and 1-, 1.78-, 3.11-, and 5.62-kHz channels of the Voyager 1 plasma wave spectrum analyzer and show variations in the amplitude of the radiation on time scales of a few to several hours. Two major effects can be seen in this figure. First, there are dramatic changes in the lower frequency cutoff of the emission; the emission disappears altogether for a few hours at fairly regular intervals. This effect was discussed in detail by *Gurnett et al.* [1980] and has recently been studied in depth at 1.2 kHz by *Leblanc et al.* [1986]. The disappearance of the emission with a periodicity of about 10 hours in the early portion of the plotted interval at the lower frequencies, such as 562 Hz and 1 kHz, reflects the passage of the spacecraft into the relatively high density plasma sheet, where the local plasma frequency is large enough to prevent the propagation of low-frequency radio waves. Gurnett et al. used this fact to map the position of the plasma sheet and boundary layer.

A second type of temporal variation evident in Figure 1 is the less dramatic variation in amplitude of the emission, which can be seen to some extent in each of the channels represented. This type of variation is not simply a cutoff effect such as is seen at 562 Hz; the minima in signal strength do not drop to the receiver threshold as during propagation cutoffs discussed above. It is this amplitude variation which is the subject of this paper. Clear evidence can be seen in Figure 1 for 10- and even 5-hour periodicities in the amplitude of the radio emission, especially in the 1.78- and 3.11-kHz channels, but also possibly at 1 and 5.62 kHz.

Figure 2 serves to demonstrate some of the differences between the temporal variations in the 562-Hz and the 3.11-kHz signals. Plotted are 16-min averages of the 3.11-kHz spectral density, indicated by the height of the

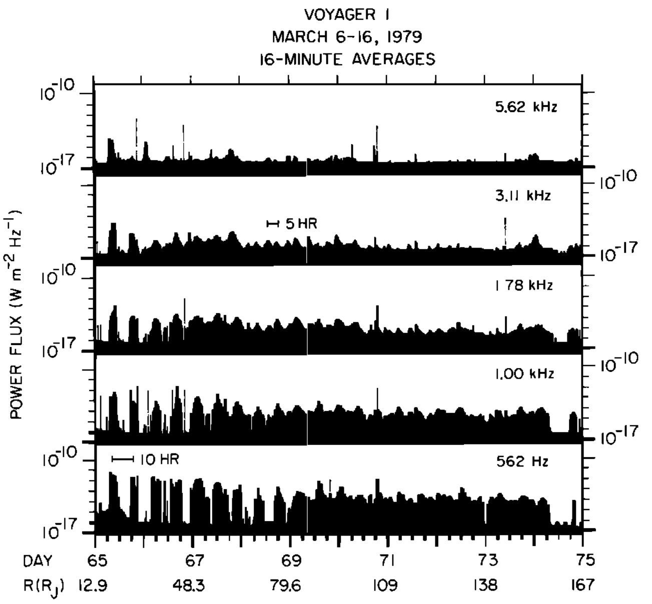

Fig. 1. Sixteen-minute averages of the electric field spectral density from several of the Voyager 1 plasma wave spectrum analyzer channels during the passage through the predawn Jovian magnetosphere. Amplitude variations at lower frequencies during the first few days can be attributed to propagation cutoffs as the spacecraft passed through the high-density plasma sheet. The remaining periodic amplitude variations are the subject of this paper.

solid black area, and the corresponding averages at 562 Hz (multiplied by 10 for clarity), indicated by the height of the shaded area. We have shown only a 3-day interval here so that on an expanded scale the differences in the profiles would be more apparent. Notice in Figure 1 that in the early portion of the interval there is a much larger amplitude variation at the lower frequency and that the dominant period is about 10 hours. There is a rather dramatic change in character of the lower frequency profile in Figure 2 beyond day 69, when the plasma sheet densities peak out at values corresponding to plasma frequencies less than 562 Hz, as indicated in Figure 2 of *Gurnett et al.* [1980].

The peaks in the 3.11-kHz channel shown in Figure 2 occur primarily at about 5-hour intervals, although a case could be made that the 5-hour peaks appear to be grouped into pairs, thereby suggesting a 10-hour component as well. Many of the 3.11-kHz peaks have relatively short rise times and longer decay times, quite different from the almost on-off nature seen on day 68 at 562 Hz. The differences in the profiles of the peaks at the two frequencies are less dramatic later in the interval.

Figure 2 also provides evidence that the mechanism controlling the amplitudes at the two frequencies is different. If the variation at both frequencies was due to cutoff effects imposed by the dense plasma sheet, then the minima and maxima should track quite well. There is general agreement in this regard evident in Figure 2; however, note that peaks near 1400 spacecraft event time (SCET) on day 68 and 1000 SCET on day 69 at 3.11 kHz correspond very closely to local minima at 562-Hz channel. It is difficult to see how the variations at 3.11 kHz can be due to a plasma cutoff effect.

Further evidence that local peaks in the density do not affect the intensity of the continuum radiation at frequencies higher than the local electron plasma frequency is given in Figure 3. Here we show two examples of high-resolution wideband observations of continuum radiation during time periods when the spacecraft passes through density enhancements. The upper panel of Figure 3 is from Voyager 1 in the near-tail region. The lower frequency extent of the continuum radiation varies from about 200 Hz near the beginning of the interval to about 300 Hz near the middle of the interval and then returns to about 200 Hz near the end. Notice that, if anything, the continuum radiation intensifies at higher frequencies (~3 kHz, for example) at the density peak. Actually, the automatic gain control of the receiver is responsible for the apparent intensification, since the intense band at the lower bound of the continuum radiation disappears, setting the gain of the receiver to a higher value. Hence we conclude that the intensity near 3 kHz remained nearly constant thoughout the interval.

The lower panel of Figure 3 shows more dramatically the lack of effect that a local density enhancement has on the intensity of continuum radiation at frequencies above the lower frequency cutoff. This example was obtained by Voyager 2 in the dayside outer magnetosphere. Of course, in this case the 3-kHz waves are cut off completely, but notice that there is no effect in the frequency range above about 4 kHz. The large amplitude excursions seen in Figure 1, particularly early in the interval and at the lower frequencies, are the result of propagation cutoff due to dense plasmas. The smaller amplitude variations, such as those at 3.11 kHz beginning on about day 66, are evidently not related to the passage of the spacecraft through high-density regions such as the plasma sheet.

The differences in the temporal variations in the frequency range ≤ 1 kHz and at 3 kHz make this study of the 3.11-kHz data quite complementary to the *Leblanc et al.* [1986] study performed on 1.2-kHz data. In the remainder of this study we will focus on the 3.11-kHz channel, since radiation at this frequency is high enough to be relatively unaffected by the presence of the plasma sheet, yet low enough to be normally trapped in the magnetospheric cavity.

Figure 4 shows 40-min sliding averages from a 10-day interval during the Voyager 1 outbound passage through the Jovian magnetosphere taken from *Kurth* [1986]. In this

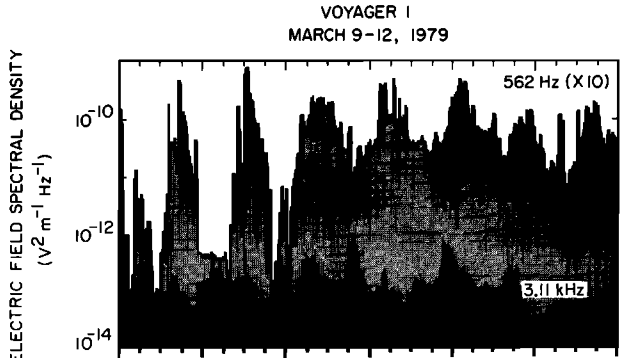

Fig. 2. The variation of the 16-min averages of the electric field spectral density at 562 Hz and 3.11 kHz. The 562-Hz trace is shifted upward by a factor of 10 for clarity. This figure illustrates the differences in temporal variations at the two frequencies. The dramatic changes at the lower frequency are due to the cutoff of waves by the high-density plasma sheet. Since the 3.11-kHz channel occasionally shows peaks when 562 intensities are at or near local minima, it is argued that the higher frequency variations cannot be due to local cutoff or refraction effects.

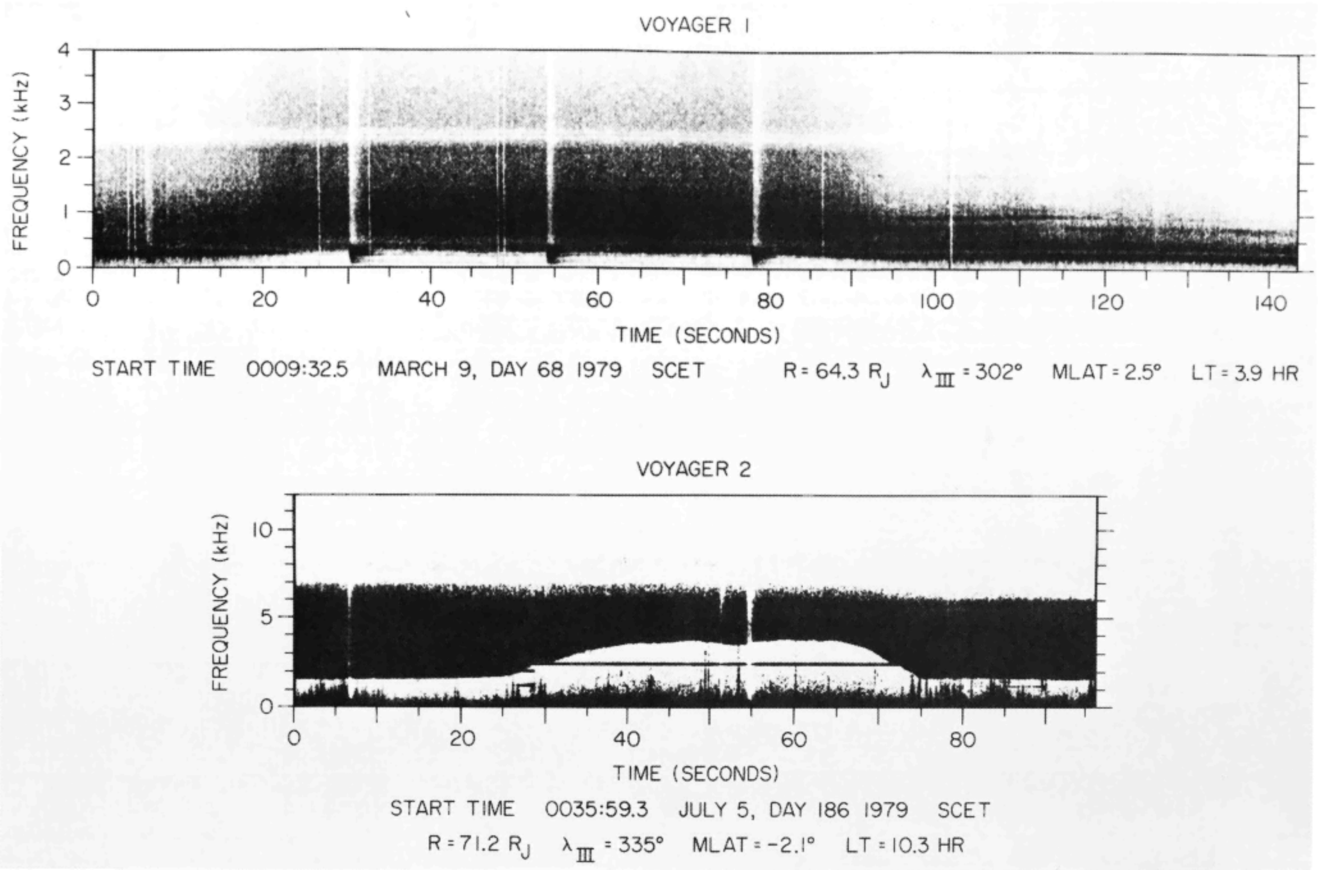

Fig. 3. Frequency-time spectrograms which show that passage of the spacecraft through a relatively high-density region results in the abrupt cutoff of waves at or very near the local electron plasma frequency but produces little or no effect at higher frequencies.

format the periodic nature of the variation is quite apparent. One can easily see a periodicity of about 10 hours, as well as a definite 5-hour component, especially between days 68 and 70. We should note that such long-term averages destroy any evidence of shorter term variations, but our intent is to understand the longer period variations.

Figures 5*a* and 5*b* illustrate the dominant periods seen in the 3.11-kHz channel. Here we have performed a power spectral analysis of the spectral density plotted in Figure 4 for two different time intervals. In Figure 5*a* we show that the dominant period, as expected, is near 10 hours for the interval from 0000 SCET on day 65 to 0800 SCET on day 68, 1979. Since the interval of analysis is fairly short, we cannot tell whether the period is exactly at the System III rotation period of 9 hours, 55 min, 29.71 s or somewhat different. In Figure 5*b* the interval analyzed is from 0800 SCET on day 68 through about 1320 SCET on day 70. It is clear that the dominant period here is about 5 hours with a strong peak also near 10 hours. Inspection of Figure 4 verifies that there should be a strong 5-hour component. The other moderate peaks in Figure 5*b* probably reflects beats between the 5- and 10-hour periods due to an artifact of the processing.

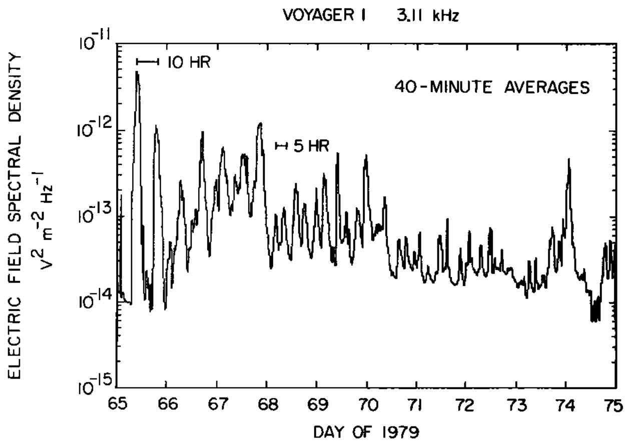

Fig. 4. Forty-minute sliding averages of the Voyager 1 3-kHz spectral densities showing strong modulation at both 10- and 5-hour periods [from *Kurth*, 1986].

Similar results can be obtained by analyzing the Voyager 2 3.11-kHz data. In fact, there seems to be an interval of about 2 days (in SCET) where the 5-hour periodicity dominates, at about the same radial distance range as that covered by the interval represented in Figure 5*b* (60–100 R_J). We do not know whether the correspondence in radial distance ranges is significant or purely coincidental.

While the 10-hour periodicity demonstrated above cannot be shown to be exactly at the system III rotation period, it is certainly reasonable to expect some relationship between the peaks and system III longitude. Figure 6 (taken from *Kurth* [1986]) is a different presentation of the data in Figure 4 organized to show the relationship between amplitude and system III longitude. The data obtained during each rotation of the system III coordinate system are plotted on a grey scale (with black being the most intense) as a function of

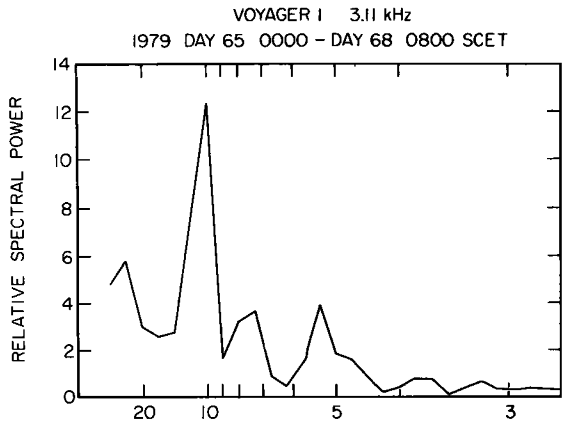

Fig. 5*a*

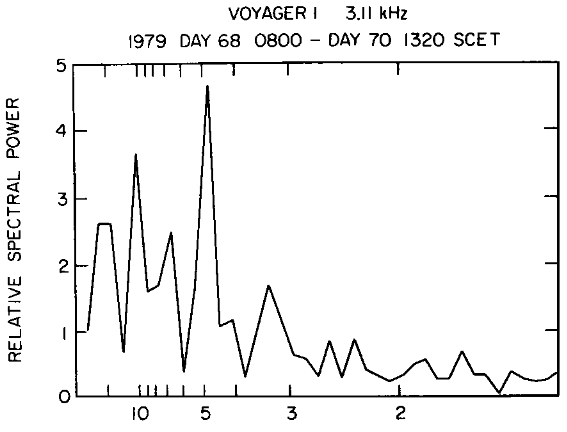

Fig. 5*b*

Fig. 5. Power spectral analysis of data presented in Figure 4. (*a*) Analysis of an interval taken from the early part of Figure 4 showing strong modulation at about a 10-hour period. (*b*) Analysis of another interval showing strong modulation at periods near both 5 and 10 hours.

longitude. Subsequent rotations are plotted in additional strips with later rotations occurring lower in the figure.

It is clear in Figure 6 that while a broad range of system III longitudes λ_{III} from ~180° to 300° is a preferred location for observing the peak in continuum radiation amplitudes, there is a secondary peak between about 45° and 120°. The magnetic dipole is tilted in the direction of 202°; hence the dominant peak obviously occurs at high magnetic latitudes. This suggests that the amplitude of the observed emission is simply a function of latitude or perhaps distance from the high-density plasma sheet. In fact, one might expect the plasma sheet to affect the observed amplitude, since the radio waves are at frequencies that are not much greater than the plasma frequency in the sheet. Refraction effects could be considerable except at positions well separated from the sheet. We have already shown, however, with the aid of Figures 2 and 3 that the 3.11-kHz variations do not appear to be due to periodic passages through the plasma sheet.

However, in order to further explore the possible effect of the plasma sheet on the amplitude of the continuum radiation at 3.11 kHz, it is first necessary to locate the position of the sheet. *Barbosa et al.* [1979] and *Gurnett et al.* [1980] have used the rise in the lower frequency cutoff of the continuum radiation spectrum to indicate passage through (or perhaps close to) the relatively dense plasma sheet. We have made use of the cutoff of the continuum spectrum in a related way to locate the plasma sheet, using data from the 562-Hz channel and simply finding the times of local minima in signal strength. While this technique does not provide sheet thickness information, as an analysis of the evolution of the spectrum does [*Barbosa et al.*, 1979], it should locate the peak of the density in the sheet or at least an indication of the closest approach to the plasma sheet in cases at large distances where complete crossings do not occur. We demonstrate the validity of this premise below.

Plotted in Figure 7 are the positions in system III longitude and radial distance of 562-Hz local minima (crosses) for the interval depicted in Figure 1. Sixteen-minute sliding averages were used to locate the minima, and we estimate an accuracy of about that magnitude in finding the time of the actual minima. The 16-min error translates into an error in system III longitude indicated by the error bars on the point near 40 R_J in Figure 7, which is typical of all the points. Note that these errors do not reflect the error in locating the actual plasma sheet unless we can validate the technique.

The trend to larger longitudes with increasing distance seen in the data in Figure 7 is a well-documented trait of

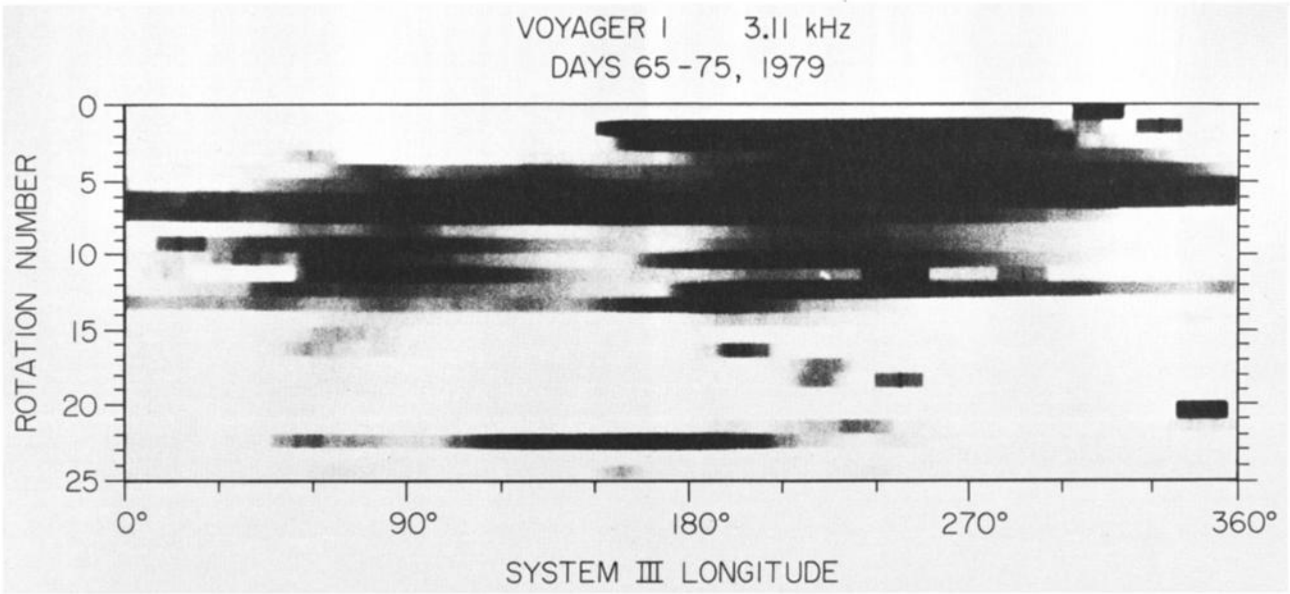

Fig. 6. Wave intensity as a function of λ_{III} (abscissa) and rotation number (ordinate) showing intensity maxima at about 70° and 215°. Data are from the Voyager 1 3.11-kHz channel for the interval plotted in Figure 1 [from *Kurth*, 1986].

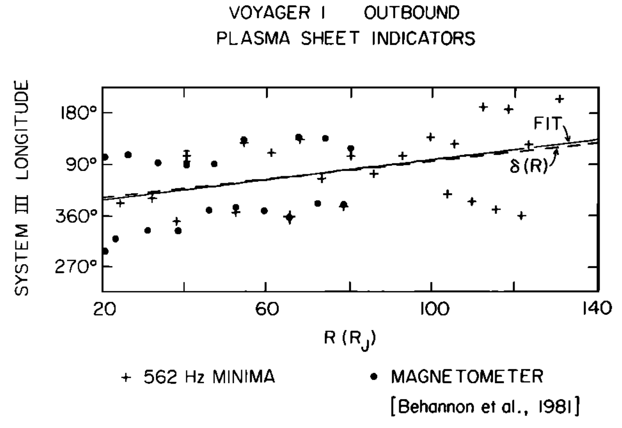

Fig. 7. Indicators of the location of the plasma sheet (crosses) as a function of $\lambda_{\rm III}$ and radial distance based on minima in the continuum radiation amplitude in the 562-Hz channel of Voyager 1. The dashed line is from *Goertz* [1981] and is related to the line of symmetry of sheet crossings (see text). The solid line is a least squares fit to the 562-Hz minima, and the excellent fit validates the use of the 562-Hz minima as plasma sheet indicators. The solid circles are the locations of current sheet crossings based on the magnetometer observations given by *Behannon et al.* [1981].

other indicators of plasma or current sheet crossings, such as maximum particle fluxes or minima in the magnetic field strength. In fact, the dashed line in Figure 7 is from *Goertz* [1981] and is defined as

$$\delta(R) = 22° + 0.8(R - 16.3) \qquad (1)$$

In equation (1), R is the radial distance from Jupiter in Jovian radii. Goertz demonstrated that various plasma, magnetic field, and plasma wave indicators of current sheet crossings would be symmetric about the line $\delta(R)$. The solid line in Figure 7 is a least squares fit to the 562-Hz minima, and the excellent correspondence with $\delta(R)$ provides strong evidence that the minima can be used as valid indicators of the plasma sheet location. We would expect that a study of the 1.2-kHz planetary radio astronomy data [e.g., *Leblanc et al.*, 1986] would yield results similar to these. We also note the large degree of scatter in the points and point out that it is similar to the scatter in the data used by *Goertz* [1981].

As a final check, the solid circles in Figure 7 are the positions of the current sheet as determined by reversals in the direction of the heliographic longitude of the magnetic field taken from Figure 4 of *Behannon et al.* [1981]. It is not surprising that these points are also symmetric about the line $\delta(R)$, since this was one of the basic results of *Goertz* [1981]. It is reassuring, though, that there is very close correspondence between the crossing positions as determined by the magnetic field and the 562-Hz minima. The minima beyond about 80 R_J in most cases represent approaches to the sheet and not full crossings.

In Figures 8*a* and 8*b* we have plotted the positions of the relative maxima of continuum radiation amplitudes at 3.11 kHz as a function of radial distance and system III longitude for Voyager 1 and 2, respectively. Typical error bars are shown for one point in each plot which are the same magnitude as the errors in Figure 7. Referring for the time being to only the crosses representing data from the outbound trajectory, it is quite evident that the continuum peaks are not influenced by the relative position of the current sheet. In fact, in Figure 8*a* the Voyager 1 peaks are seen in two longitude ranges whose average location are at 70° ± 8° and 215° ± 16°. Figure 8*b* shows a similar result from Voyager 2; however, the average longitudes for the peaks are 104° ± 17° and 246° ± 19° in this case. For both data sets there is considerable scatter at distances less than about 60 R_J. The average locations of the peaks for both spacecraft mentioned above are those using only the points beyond about 60 R_J. We will discuss the possible significance of the shift to larger longitudes of the Voyager 2 set with respect to the Voyager 1 data set below.

The solid lines in Figures 8*a* and 8*b* are least squares fits to the positions of the maxima (using all of the points) and are shown to demonstrate a trend which differs significantly from $\delta(R)$ as well as the trend of the minima at 562 Hz shown in Figure 7, further differentiating between the effect of plasma sheet crossings at 562 Hz and the variations at 3.11 kHz. Since Figure 7 is a plot of local minima in signal strengths and Figures 8*a* and 8*b* are based on peaks, we have checked to see that trends can be found in the positions of the signal minima at 3.11 kHz that are similar to those seen in the peaks shown in Figure 8. Figure 9 shows the result of this analysis for the Voyager 1 outbound data set. While the positions of the minima are necessarily offset from those of the peaks, the trend to smaller system III longitudes is unmistakable. The slopes of the fitted lines are very similar to those shown in Figure 8*a*. Were the minima a cutoff effect related to the spacecraft's passage through or proximity to the plasma sheet, the trend should be symmetric about the line $\delta(R)$, as were the minima at 562 Hz shown in Figure 7.

The determination that the relative position of the plasma sheet does not affect the observed amplitude of the contin-

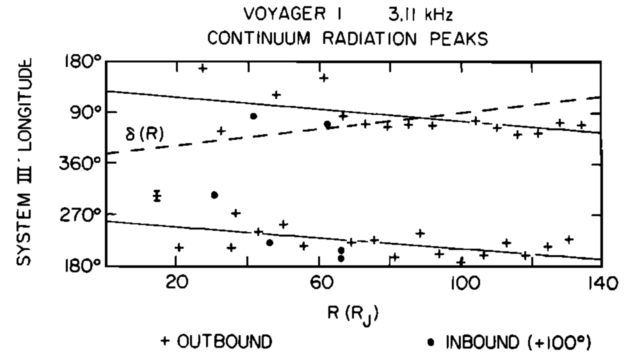

Fig. 8*a*

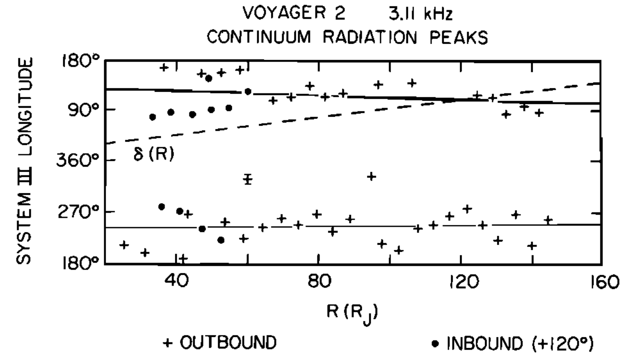

Fig. 8*b*

Fig. 8. (*a*) Locations of continuum radiation peaks in $\lambda_{\rm III}$ and radial distance for the inbound (solid circles) and outbound (crosses) portions of the Voyager 1 encounter. The inbound points have been shifted by 100° to account for the difference in local time of the two legs of the trajectory. Notice that the peaks are not related to sheet crossings (which would be symmetric about the line $\delta(R)$). (*b*) Same as in Figure 8*a* but for the Voyager 2 encounter. The peaks lie at longitudes about 25° or 30° higher than for the Voyager 1 peaks.

uum radiation and that the peaks are seen at nearly constant system III longitudes implies that the amplitude modulation is associated not with the location of the observer but with the position or state of the source. In fact, these observations suggest that the source may be rotating with the planet much as a searchlight does, since the peaks are observed at nearly constant system III longitude. If the source were rotating with the planet, one would expect to see maxima in the inbound observations of continuum align at the same longitudes as those observed during the outbound passages. In fact, this does not appear to be the case. The data seem to be better organized by shifting the inbound observations by an angle corresponding to the difference in local time of the inbound and outbound trajectories. In Figures 8*a* and 8*b* the positions of the inbound continuum radiation maxima are plotted with solid circles and have been shifted by 100° for Voyager 1 and 120° for Voyager 2. This organization suggests that the continuum amplitudes peak when the Jovian magnetic dipole is oriented in specific directions with respect to the sun and that the radiation is modulated in a clocklike fashion as opposed to being swept around as a searchlight.

Since the number of inbound peaks is limited in both encounters and the radial distances of the inbound points are generally within the range less than 60 R_J where the scatter is greatest, it must be said that the improvement in organization of the data by shifting as described above is not spectacular. It is reassuring, however, that treatment of the data sets from both encounters in the same way yields consistent results; both data sets taken separately seem to imply that it is the orientation of the dipole in local time which is important.

The slopes of the two Voyager 1 lines and the upper of the Voyager 2 lines in Figure 8 are all negative. The lower Voyager 2 line has a slightly positive slope. Inspection of the Voyager 1 data points beyond about 62 R_J shows slopes which are much closer to zero than the illustrated fits. Since the Voyager trajectories only asymptotically approach fixed local times at large distances, the drift of the peaks to smaller system III longitudes and the leveling of the slope at larger distances seen in the two Voyager 1 data sets in Figure 8*a* and the upper Voyager 2 set in Figure 8*b* are consistent with a source which is fixed in local time and modulated in clocklike fashion. Scatter in the lower Voyager 2 data set in Figure 8*b* may have masked this effect.

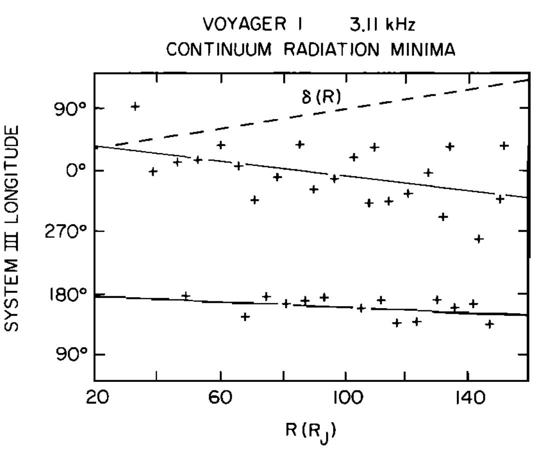

Fig. 9. Similar to Figure 8*a*, except that this study uses the local minima at 3.11 kHz instead of peaks. The trend is very similar to that in Figure 8*a* and does not track the trend seen in the 562-Hz minima shown in Figure 7.

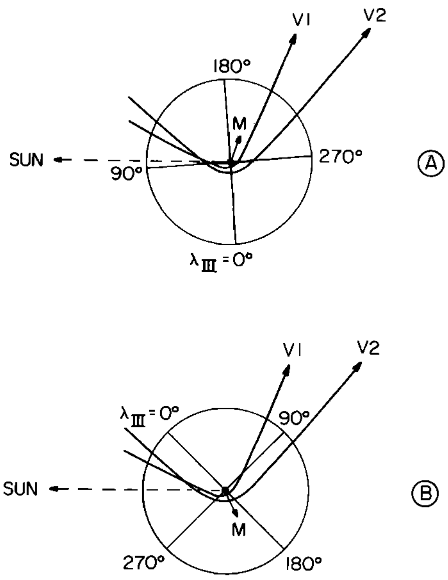

Fig. 10. Schematic drawings showing the typical relative orientation of the dipole moment, the sun, and the two Voyager trajectories when 3-kHz continuum radiation amplitudes are peaked.

Further supportive evidence that the orientation of the magnetic dipole in local time is important is the fact that for the outbound data sets the preferred Voyager 1 system III longitude is 25° or 30° less than that for Voyager 2. The difference in local time between the two outbound trajectories is about $1\frac{2}{3}$ hours or 25°. Hence the shift in preferred longitude is almost entirely compensated for by the change in local time of the trajectories.

The above analysis of the circumstances under which the continuum radiation is observed to be at maximum intensity implies that the preferred orientation of the dipole is with the sun over the 95th magnetic (system III) meridian. Every time this geometry is achieved, the emission intensity is at its peak. Hence the emission is modulated in clocklike fashion. A secondary peak is often seen when the sun is over the 315th meridian. The geometry of the sun, Jupiter, the two Voyager trajectories and the orientation of the dipole is schematically depicted in Figure 10 for the two situations in which the 3.11-kHz amplitudes are likely to be at a peak. For each geometry the scatter in the points in Figure 8 and the width of the peaks seen in Figure 6 imply that rather broad ranges centered about those depicted in Figure 10 are associated with peaks.

3. DISCUSSION

On one hand, the amplitude modulation of the trapped Jovian continuum radiation is somewhat surprising, in that the emission is generally trapped within the magnetospheric cavity; hence local intensifications are rapidly distributed through the cavity via multiple reflections, and an observer sees a roughly spatially averaged intensity. On the other hand, there are very few magnetospheric phenomena at Jupiter which do not show some periodicity related to the spin of the planet, so we should not be too surprised to see that the continuum radiation follows suit. Should the intensification of continuum sources be widespread or organized, even the effects of multiple reflections would not smooth out the temporal profile for the received amplitude. Perhaps the most surprising result is that what we believe to be a distributed source (based on our understanding of the terrestrial source) could be organized to the extent of producing reproducible amplitude profiles.

The real issue here is to determine what the periodicity says about the generation of the radio emission and, more important, the processes which occur in the magnetosphere. Unfortunately, since these observations are remote and we can only surmise (by the frequency of the emission and models of the plasma frequency) the location of the widely distributed source, it will be very difficult to draw any definite conclusions about the generation mechanism from the observations presented herein.

To avoid a detailed discussion of generation mechanisms, let it suffice to say that it is generally quite well accepted that the continuum radiation is generated via mode conversion from intense electrostatic waves near the upper hybrid resonance frequency [*Kurth et al.*, 1981] through either a linear mechanism (see, for example, *Jones* [1976]) or a nonlinear mechanism (see, for example, *Melrose* [1981]). Consequently, the radiation near 3 kHz is thought to be emitted in numerous narrow bands from upper hybrid waves located on the density gradient either on the outer edge of the Io torus (middle magnetosphere source) or just inside the magnetopause [*Gurnett et al.*, 1979, 1983; *Jones*, 1980; *Scarf et al.*, 1981] (magnetopause source). An important question is which of these two possible sources is dominant.

From the variation of plasma frequency with radial distance (see, for example, *Gurnett et al.* [1981*b*]) we can envision a possible source of 3-kHz emissions located in the middle magnetosphere in a rather broad range of distances around 25 R_J (if the source is in the plasma sheet) or perhaps much closer to Jupiter if the source is north or south of the sheet, where the plasma frequency is smaller at a given distance. This places the middle magnetosphere source beyond the Io torus, most likely on density gradients either on the extreme outer edge of the torus or north or south of the plasma sheet (or torus). If one assumes that the middle magnetosphere is the primary source region, there must be some local time variation of conditions on field lines which thread the middle magnetosphere to explain the apparent importance of the dipole-solar direction alignment.

Goertz and Baker [1985] discuss a mechanism which varies the longitudinally averaged Pedersen conductivity in the ionosphere due to asymmetric solar illumination of the feet of high-latitude field lines. The variation in Pedersen conductivity gives rise to a variation in the rate of "slippage" of field lines which are mass loaded by Iogenic plasma. In fact, Goertz and Baker calculate that the maximum in average conductivity will occur when the subsolar longitude is within 40° of $\lambda_{III} = 100°$. This orientation agrees well with the primary preferred dipole orientation for the 3-kHz continuum peak, as seen in Figure 10*a*. It is not clear that this model can produce a secondary maximum when the subsolar system III longitude is near 315°, however. Also, it is not known how the increased Pedersen conductivity can affect the generation efficiency of trapped continuum radiation.

The other possible source region is near the magnetopause itself. It is easy to imagine that periodic variations at the solar wind interface could modulate the intensity of waves generated near this boundary through changing magnetic field conditions or variations in the electron distribution function brought about by time-varying diffusion or reconnection processes. Observations of upper hybrid emissions near the magnetopause [*Gurnett et al.*, 1979, 1983] suggest that the magnetopause might be the location of the continuum radiation source. In contrast, *Kurth et al.* [1980] cite little evidence for the electrostatic source emissions either at the magnetic equator near 25 R_J or north or south of the plasma sheet (torus) closer to Jupiter. Hence we are compelled to consider the magnetopause an important source of continuum radiation, if not the primary source. This is the same conclusion reached by *Leblanc et al.* [1986], albeit by a different line of reasoning.

The modulation of continuum radiation intensities has some interesting implications on the various models explaining temporal variations in Jupiter's magnetosphere. These various models are discussed extensively by many authors (see, for example, *Schardt et al.* [1981], *Vasyliunas and Dessler* [1981], *Hill et al.* [1983], and *Schardt and Goertz* [1983]). The three primary models are the clock, the magnetic anomaly, and the disc models. In fact, all three models are used to explain one or more periodic variations observed in the Jovian magnetosphere. One phenomenon which could be relevant to this paper is the clocklike modulation of Jovian high-energy (greater than a few MeV) electrons [*Chenette et al.*, 1974; *Simpson et al.*, 1975; *Schardt et al.*, 1981]. These electrons seem to be released when system III longitude $\lambda_{III} = 240°$ points in the tailward direction ($\lambda_{III} = 60°$ is the subsolar longitude). This phenomenon is the classic application of the clock model, because the observation of the phase of the electron flux variations is independent of the observer's location. Supporters of the magnetic anomaly model argue that their model provides the longitudinal asymmetry required to trigger the electron releases due to some preferred orientation of the anomaly with the solar wind interface—most likely the dawn magnetopause [*Vasyliunas and Dessler*, 1981; *Schardt et al.*, 1981] (see also *Goertz and Baker* [1985]). The disc model is clearly ruled out by the fact that only the 10-hour period is evident in the electron fluxes.

Five-hour periodicities, like those observed in the continuum radiation peaks, are usually associated with the disc model. For a restricted range of observer latitudes the magnetodisc will sweep over the observer twice per planetary rotation, thereby providing a 5-hour periodicity to a number of measurements sensitive to the plasma and/or fields in the disc. There are variations on this model which involve adding bending and finite propagation times to a purely rigid disc model. We have shown the existence of 5-hour periodicities in the 3.11-kHz continuum radiation which are apparently not the result of simply passing through the plasma sheet twice per planetary rotation. That is, the observed 5-hour periodicities are not produced locally; however, the rocking of the dipole may change conditions in a continuum source region at the magnetopause and therefore cause amplitude variations in the radio emission.

Hence the 3.11-kHz variations reflect the influence of the disc model because of the 5-hour periodicity which is observed; however, we suggest that the variation mechanism is operative at the source as opposed to the observer, since we have demonstrated that the 3.11-kHz peaks are not always governed by the position of Voyager with respect to the sheet. The continuum variations also reflect the clock model because of the importance of a nearly fixed orientation of the dipole with respect to the sun. Hence we may see a connection between two of the existing models of the Jovian magnetosphere operative in the modulation of continuum radiation amplitudes. The influence of the solar wind interface tends to emphasize the importance of the magnetopause source of continuum radiation, and *Schardt et al.* [1981] have already pointed out the likelihood that the "clock" electrons are released from the region of the dawn magnetopause, strongly suggesting a tie between the two processes. The tie, however, must be somewhat indirect, since electrons responsible for the generation of upper hybrid resonance bands have energies in the keV range—much less energetic than the "clock" electrons.

Each of the aforementioned models was developed to explain a set of observations; for example, the clock model specifically addressed the periodic change in the spectral index of electrons released from the magnetosphere. Proponents of the anomaly model would argue that their model is consistent with a number of different observations. In reality, however, each of these models has a degree of validity, but the Jovian magnetosphere appears to require all of them (or certainly more than one of them) to explain the full range of observations. That is, the Jovian magnetosphere is more complex than any of the models and supports some processes which are consistent with each. Hence it is natural that a phenomenon may show characteristics which reflect features of more than one. It appears that the trapped continuum radiation is just such a phenomenon.

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