THE BROADBAND JOVIAN KILOMETRIC RADIATION STATISTICAL PROPERTIES AND SOURCE MODEL

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Abstract

Using the Voyager 1 and 2 (V1 and V2) Planetary Radio Astronomy experiments, we have analysed the data in the kilometric wave–length range for 850 Jovian rotations (from January 14, 1979 to December 31, 1979), this period including pre– and post–encounters for V1 and V2. Statistical studies of the broadband Kilometric Radiation (bKOM) reveal many new results on this emission. We show that it consists of two components polarized in the opposite sense, a “main” and an “intermittent” component. The occurrence probability and the emitted frequencies are strongly dependent on the observer’s latitude. At the highest latitude the occurrence is nearly constant between 60 and 300 kHz. At the lowest latitude there is an important decline of the occurrence probability and the peak of frequency occurrence is at 80 kHz. Taking into account the polarization response of the PRA antennas, we find that the polarization of the emission is right–handed before and after encounter for the main component and left–handed for the intermittent component. Our results are discussed in terms of a new rotating source model. In this model the source regions are at the inner boundary of the Io torus all around the planet and the emission is beamed into a hollow conical sheet whose axis coincides with the magnetic dipole of the planet. The lowest magnetic latitude of the beam deduced from the observations is about 11° for the main component.

1 Introduction

One of the discoveries made by Voyager 1 and 2 (V1 and V2), on their flyby of Jupiter was the detection of a radioemission at kilometric wavelengths (JKR), from 1 MHz to 10 kHz. The first evidence appeared in the Voyager Planetary Radio Astronomy (PRA) data when the spacecraft were more than 2 AU away from the planet (Desch and Kaiser, 1980). Two distinct emissions have been identified: a broad–band component (referred to as bKOM) and a narrow–band one (nKOM). This latter was first described by Kaiser and Desch (1980). In the present paper we will concentrate on the bKM component.

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The broadband component was briefly reported in the first accounts of V1 and V2 Jupiter encounters (Scarf et al., 1979; Warwick et al., 1979a, b; Kurth et al., 1979). The spectral and temporal characteristics were described by Kurth et al. (1979, 1980) in the frequency range 10–50 kHz. The occurrence rate, polarization and intensity spectra have been studied by Desch and Kaiser (1980) in the range of 20 kHz – 1 MHz. They argue that the polarization data are suggestive of a radiosource that remains fixed rather than rotating with the planet. They conclude that the radiation must be generated in the L.O. mode (Left–hand ordinary) and that there is a Northern hemisphere source located in the dayside hemisphere of the planet. However ray–tracing calculations made by Green and Gurnett (1980) suggest that the source region is located near Jupiter on field lines passing through the Io torus and distributed throughout all Jovian longitudes.

All of these analyses were made from data obtained during the two short periods of encounter with Jupiter. The pre–encounter observations were made at 10:30 local time and 3.2° Jovicentric latitude for V1 and 9:30 local time and 7.5° Jovicentric latitude for V2. The post–encounter observations correspond to 4:15 local time and 5.3° for V1 and 3:0 local time and 5.7° for V2 (Fig. 1).

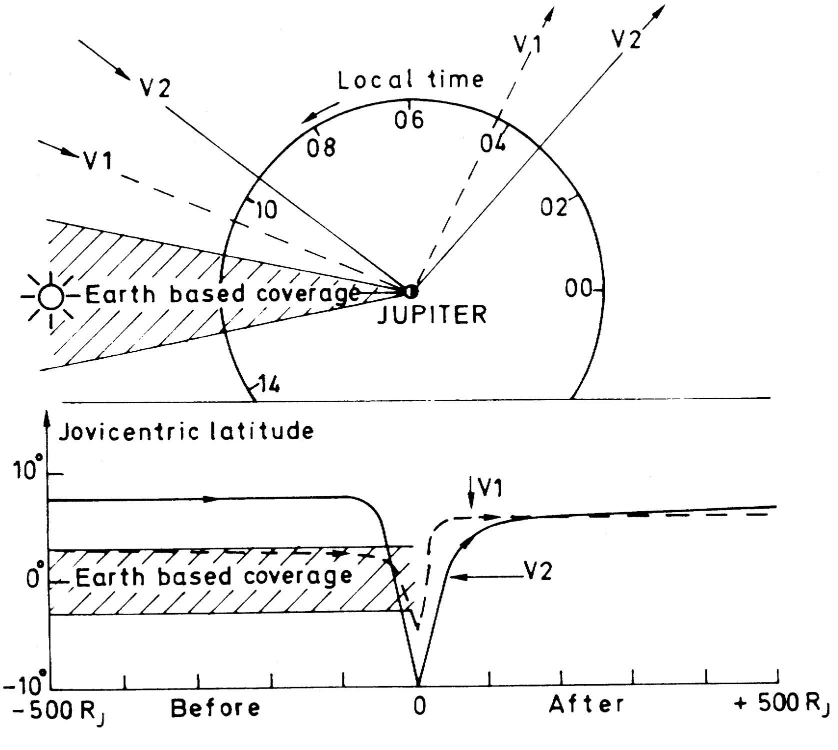

Figure 1: Coverage in local time and Jovigraphic latitude by Voyager 1 and 2 and by Earth–based observations (after Alexander et al., 1980).

The purpose of the present paper is to give additional results on the polarization and the characteristics of the bKOM source. We have analysed data as observed by V1 and V2 PRA experiments during 850 Jovian rotations from 790114 to 791231. This period includes the pre– and post–encounters for V1 and V2 where the observations were made on the day–side and on the night–side of Jupiter, for different Jovicentric latitudes and at distances from – 2180 (Jovian Radii) R_J through + 3215 R_J, respectively. In the first section we describe the observations and our method of analysis. Statistical studies on the occurrence in CML (System III Centrul Meridian Longitude) and on the frequency emitted are given for V1 and V2 observations. Comparisons are made before and after encounters, when each spacecraft was at the same distance from Juplter, and for simultaneous observations when the two spacecraft were far away from each other. The apparent polarization of the emission is analysed for each Jovian rotation. Taking into account the polarization response of the PRA crossed–monopoles antenna, the real polarization of the radiowave is deduced.

The results are discussed in the second section in order to determine more precisely the emission mode, the localization of the sources and the propagation effects through the Io torus.

2 The Observations

The PRA instrument has been described by Warwick et al. (1977). A swept–frequency receiver covers the band from 40.2 MHz to 1.2 kHz, and a pair of orthogonally mounted 10m monopoles provides measurements of the right–hand (RH) and left–hand (LH) circular components of the radio emission.

For the present study we have plotted intensity versus time at 12 frequencies between 481.2 kHz to 1.2 kHz for each Jovian rotation (Fig. 2). Two different symbols show the observed sense of polarization: RH is represented by a dashed line and LH by a full line. When the observed emission is strongly polarized, the two signals are clearly separated, otherwise the two signals are nearly identical. In Figure 2, we can easily distinguish bKOM from nKOM: bKOM emission is very bursty, generally centered on CML 120° to 270° and observed on most of the displayed channels, whereas the nKOM component is characterized by a smooth emission observed only on a few channels.

Furthermore, bKOM emission shows a characterlstic V–shaped envelope in the dynamic spectrum before encounters (low frequencies on the top). In Figure 3 the frequency drift of the two branches is about 5 kHz/min and -3 kHz/min in the range of 80–150 kHz. The V–shaped envelope could be coincident with positively or negatively drifting features. These drifting features have been reported by Kurth et al. (1979), Warwick et al. (1979) and Boischot et al. (1981) who measured a drift rate of 1–10 kHz/min.

For each Jovian rotation we have noted the CML occurrence of bKOM, the emitted frequencies and the apparent polarization: these are plotted for each set of hundred rotations: the occurrence in CML at 58 kHz and the apparent polarization in Figure 4 and the emitted frequencies ln Figure 5. The frequenzy of 58 kHz has been chosen since most of the bKOM emissions are covered in this domain, as shown in Figure 5. Where the lower frequency limit is higher than 58 kHz, the measurement refers to the lowest frequency observed.

Desch and Kaiser (1980) have already shown that there are important variations of bKOM in the CML occurrence statistics, in the sense of polarization and in the frequency coverage, from one observing perspective to another. In order to follow the evolution of these

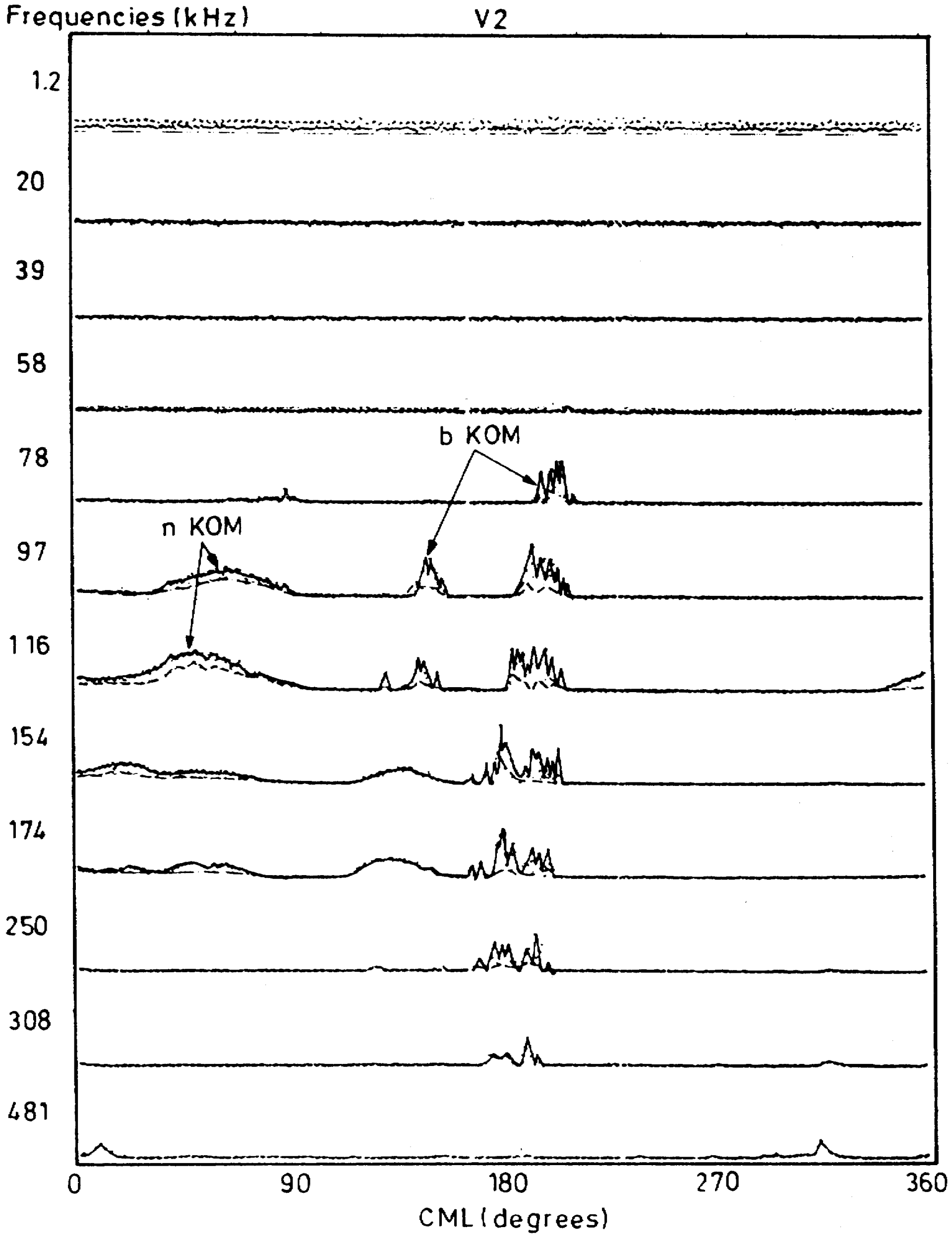

Figure 2: Jovian radioemission in the kilometric wavelength range during one Jovian rotation (790822). Two symbols are used to identify the apparent polarization: solid line – Left hand (LH) sense and dashed line – right hand (RH) sense. The broad–band (bKOM) and the narrow–band (nKOM) call be easily distinguished.

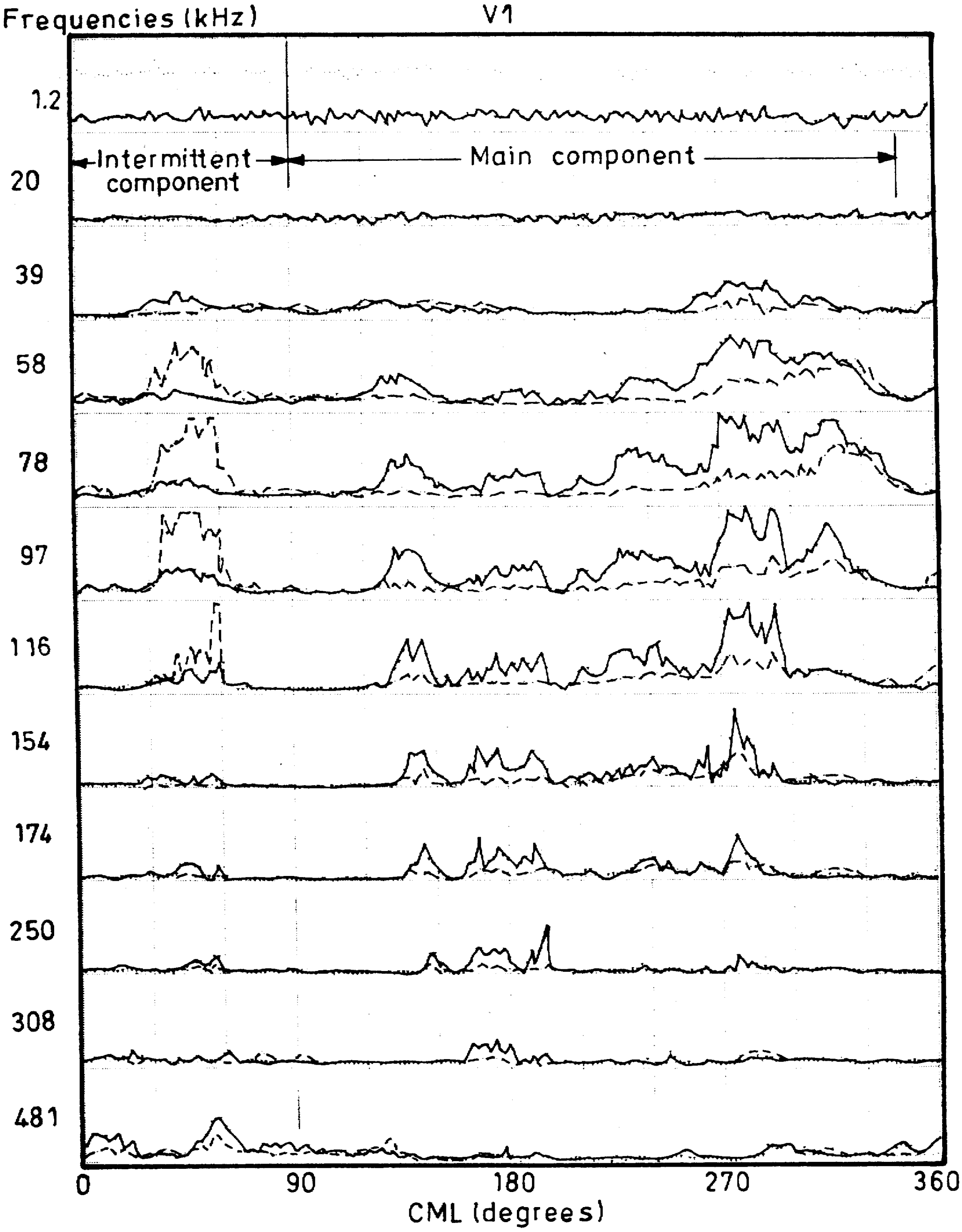

Figure 3: bKOM emission consists of two components polarized in the opposite sense: the main and the intermittent components.

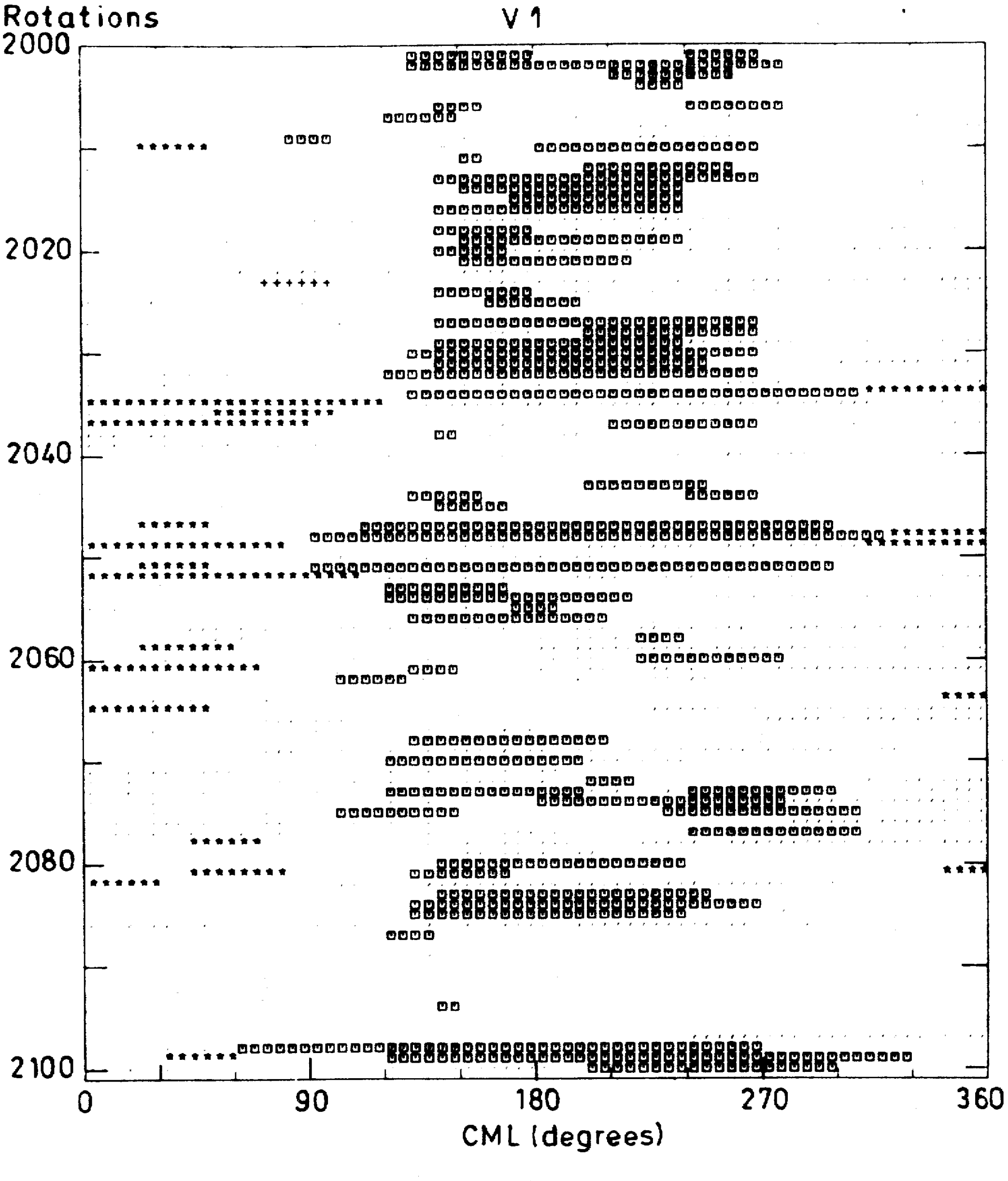

*Figure 4: Occurrence in CML of bKOM emission as observed by V1 for one hundred of rotations (from 790407 to 790519). The apparent sense of polarization is indicated by □ (LH) and * (RH). The main emission is statistically observed in the CML range of 120° – 300° and the intermittent one in the ranges of 0° – 90° and 300° – 360°. The slashes (/) indicate periods of no observations by the spacecraft.*

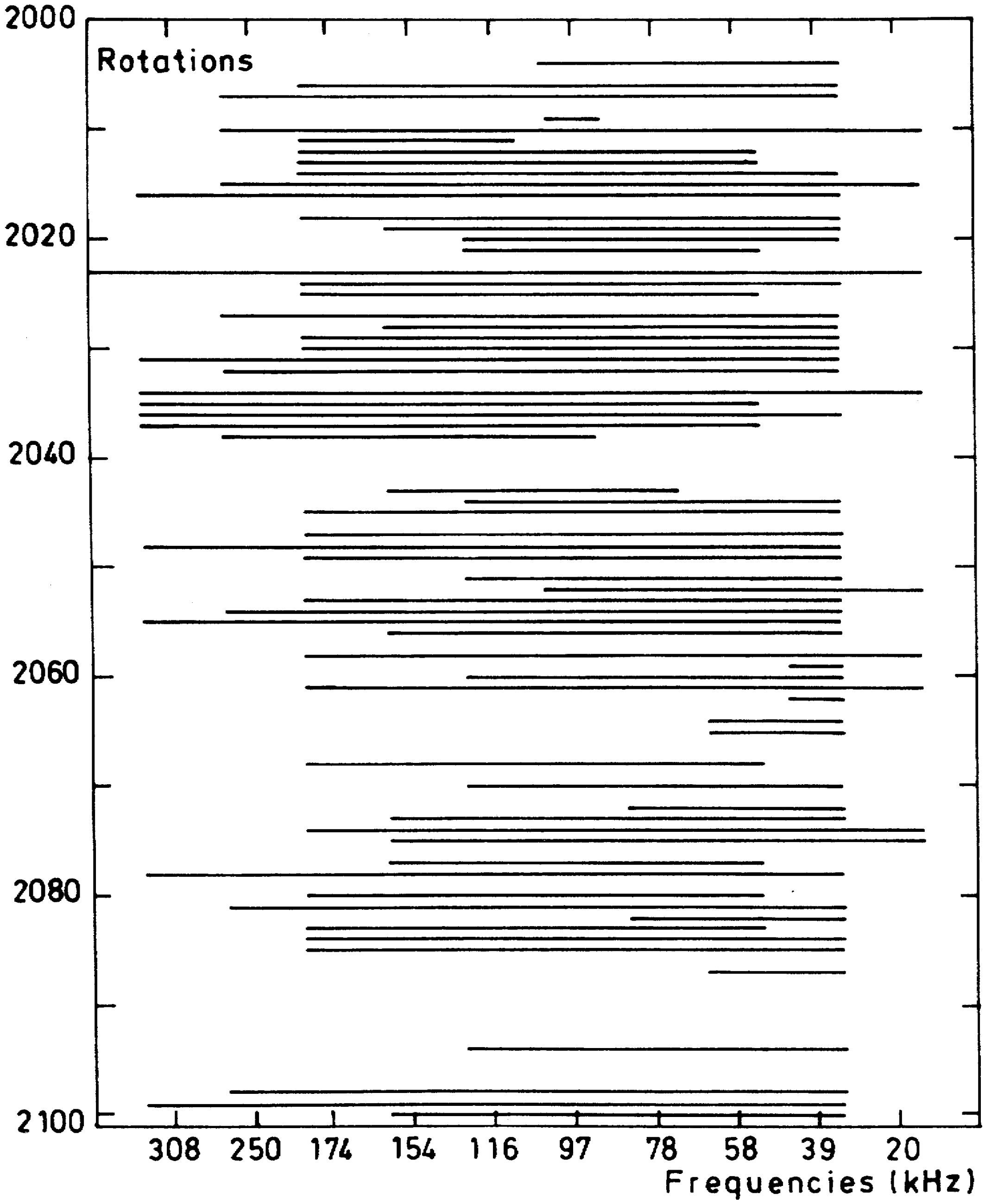

Figure 5: Frequency coverage of the bKOM for one hundred of rotations (from 790407 to 790519) . Most of the emisson occurs in the range of 39 kHz – 174 kHz.

variations and to distinguish local time, latitude and distance effects, we have divided the entire period under study into several shorter periods, and examined the statistics in each of these short periods. The corresponding geometrical configurations and distances are given in Table 1 and Table 2. Comparisons can be made between the sets of data obtained as follows:

- before and after encounters from V1 and then from V2 observations.
- before encounters and at the same distance from Jupiter
- after encounters and at the same distance from Jupiter
- from simultaneous observations from V1 and V2.

Spacecraft	Distance range (R_J)	Declination	Local time
V1	-[600 – 20]	3°2	10.30
V1	+[20 – 600]	5°2	04.15
V1	+[500 – 1000]	5°3	04.15
V1	+(1000 – 1672]	5°3	04.15
V1	+[2385 – 3215]	5°3	04.15
V2	-[1664 – 1000]	7°5	09.30
V2	-[1000 – 28]	7°2	09.30
V2	+[85 – 353]	5°	03.00
V2	+[503 – 1000]	5°7	03.00
V2	+[1000 – 1670]	6°1	03.00

Table 1:

2.1 Occurrence in CML:

- Before encounters: the maximum occurrence is at 180° – 200° CML for V1 and V2 observations (Fig. 6 and Fig. 7). This result is in agreement with that found by Desch and Kaiser (1980) at 97 kHz. Outside the main peak there are very few emissions at longitudes between 0° – 120° and 270° – 360° (in Desch and Kaiser's plot, the rather high level of activity in these longitude sectors is due, as noted by these authors, to a false identification of nKOM events).
- Just after encounters: there are two main peaks, the first at 140° and the second, less prominent, at about 240°. These two peaks are more clearly defined in Desch and Kaiser's plots as they took a higher threshold than in the present work.
- Far from Jupiter: the two peaks are still observed. The first peak remains at 140–150° but the second one drifts towards higher longitudes, about 270° for V1 observations and some 290° for V2 observations. Between 140° and 270° the emissions are less often observed.

Spacecraft	Distance range (R_J)	Declination	Local time
V1	-[600 – 20]	3°2	10.30
V1	+[20 – 600]	5°2	04.15
V2	-[1000 – 500]	7°5	09.30
V2	+[500 – 1000]	5°7	03.00
V1	-[600 – 20]	3°2	10.30
V2	-[600 – 20]	7°5	09.30
V1	+[500 – 1000]	5°2	04.15
V2	+[500 – 1000	5°7	03.00
V1	+[2385 – 3215]	5°2	04.15
V2	+[540 – 1150]	6°1	03.00

Table 2: simultaneous observations 790829 – 791031

Outside the main peaks, there is an important level of acivity at 0° < CML 120° and 300° < CML < 360°. This latter emission is "intermittent", as opposed to the "main" emission (which is generally observed for most Jovian rotations) and its polarization sense is reversed. The characteristics of this intermittent emission are being developed in another section.

It can be seen that, from Figure 6 and 7, when the observations were made at the same local time but at different Jovicentric latitudes, a single peak is observed at the same longitude. We can, therefore, distinguish between latitude and local time effects: for day–side observations there is a main peak occurring at CML ≅ 200°.

After encounters, the local time and latitude of the two spacecraft are nearly the same, which makes it difficult to distinguish between the two effects. It is probable, however, that the two peaks observed after encounters are characteristic of nightside observations.

3 Comparison of Occurrence Probability Diagrams

The areas of the histograms shown in Figures 6 and 7 are representative of the bKOM absolute occurrence probability for each period. We have compared the areas of the histograms for different observing perspectives as described in Table 2. The results are:

- V1 and V2 observations before encounter (V2 was at a higher declination than V1): the area of V2 histogram is twice that of the area of the V1 histogram. On the other hand we notice that the width of the peak is larger for V2 observations than for V1 observations. We conclude that the latitude of the observer strongly affects the probability of detecting bKOM (Fig. 7), a result which confirms that of Desch and Kaiser (1980).

- V1 and V2 observations after each encounter (each spacecraft was at the same declination): the two areas are almost equal.
- Simultaneous observations made by V1 and V2 after encounters: the averaged distance of V1 from Jupiter was 3000 R_J and that of V2 1300 R_J, that is V1 was 9.3 times further than V2. When we compare the two areas there is only a factor of 1.9 and we notice that the peak at 140° CML is still very important. This result shows that focalisation effects could be important.

We have shown that the occurrence probability in terms of CML strongly depends on local time. It appears from these comparisons that slight changes in latitude of the probes strongly affect the occurrence probability. The spacecraft trajectories have brought observations at three different latitudes. The highest latitude corresponds to the largest occurrence probability (V2 before encounter), and the lowest latitude to the smallest one (V1 before encounter). We shall see that this latitude effect is sustained by variations in the frequency range of occurrence.

3.1 Frequency Range of Occurrence

For a given period we have plotted histograms showing the number of rotations where the emission occurs at a given frequency. The periods have been chosen for different observing view point as listed in Table 2. We have not taken into account the emission at frequencies higher than channels 308 kHz since there could be confusion with the Hectometric Jovian emission (HOM) mainly observed between 300 kHz and 2000 kHz. From our PRA records the low frequency cut off of bKOM emission is about 39 kHz and only a few events are observed down to 20 kHz. We notice that at this frequency there could be a confusion with other very low frequency emissions. The results are shown in Figure 8.

When the two spacecraft were at the same declination (∼ 5°) and local time (∼ 4:00), the frequency spectra of occurrence are similar within the same distance interval. At the same local time (∼ 10:00) but at different latitudes (3° and 7.5°) more emissions are observed in the high frequency range for the higher latitude. This is also true when the local times are different: the comparison of the frequency spectra of V2 observations before and after encounter shows that, when the latitude decreases from 7.5° to 5.5°, there are fewer emissions observed in the high frequency range. On the other hand, V1 pre–encounter spectra show slight differences whereas the spacecraft latitudes are, respectively 3.2° and 5.5°. We notice that at 3.2° of latitude there are fewer emissions observed in the low frequency range ($f < 100$ kHz) before V1 encounter. Finally when the two spacecraft were far from Jupiter, the shape of the frequency spectrum of occurrence does not change.

These results show that:

- At 7.5° of latitude the frequency spectrum of occurrence is very flat between 60 kHz and 300 kHz

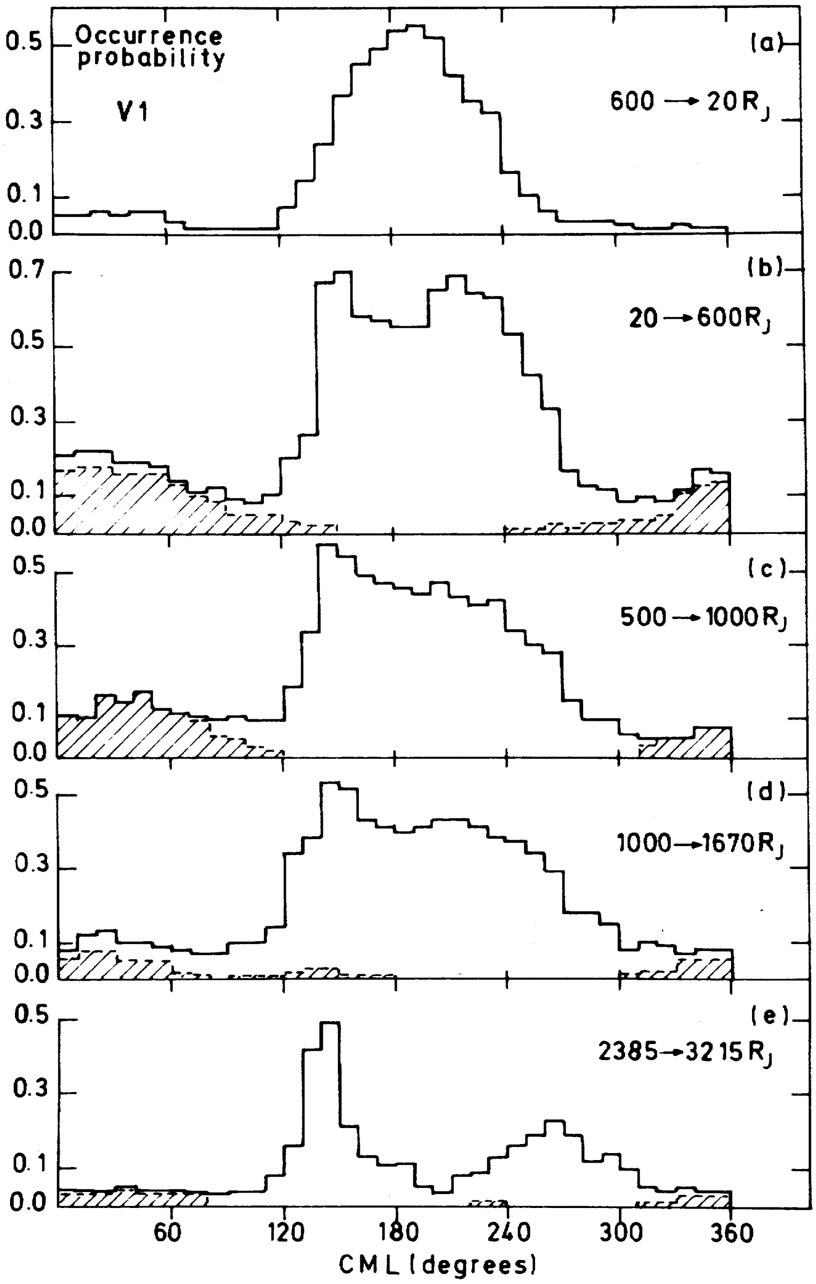

Figure 6: Probability of occurrence in CML of bKOM emission observed by V1 at different distances from Jupiter. The white area refers to the main component and the shaded area to the intermittent component.

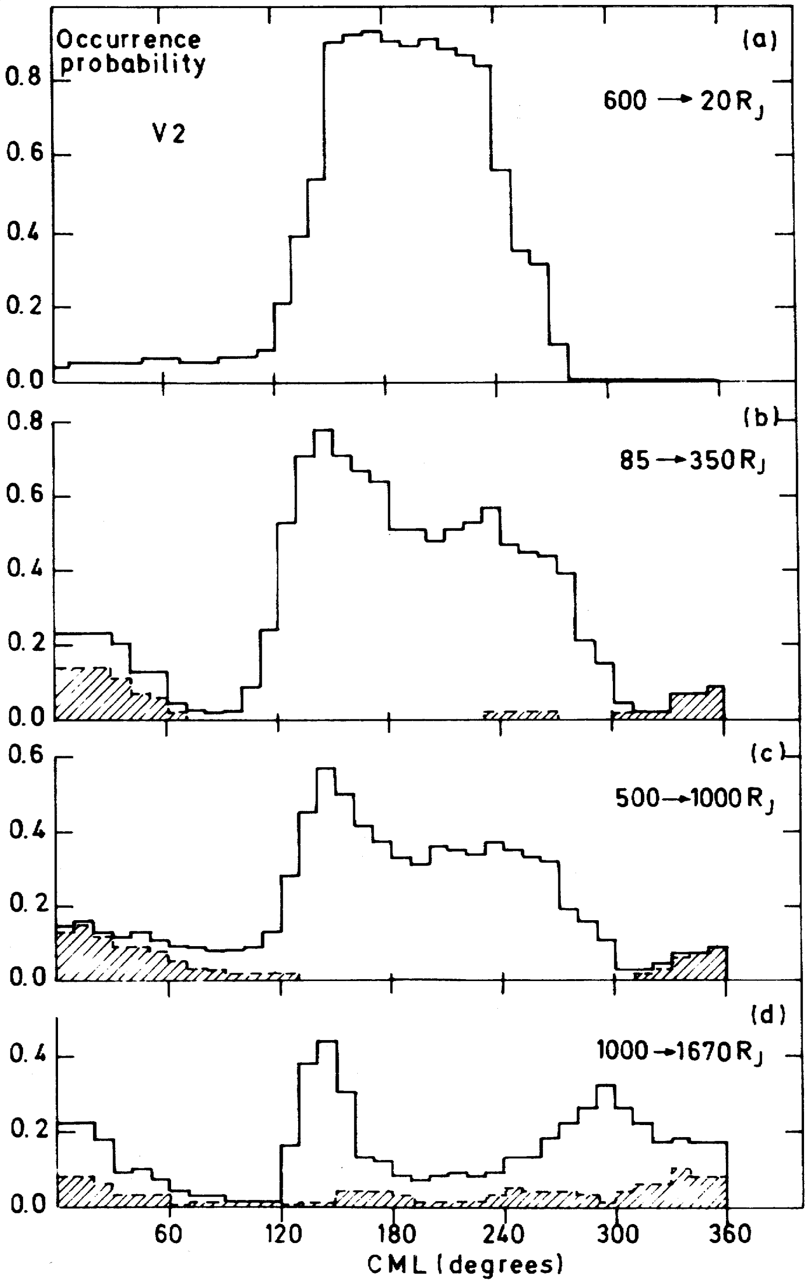

Figure 7: The same as Figure 6 but for V2 observations.

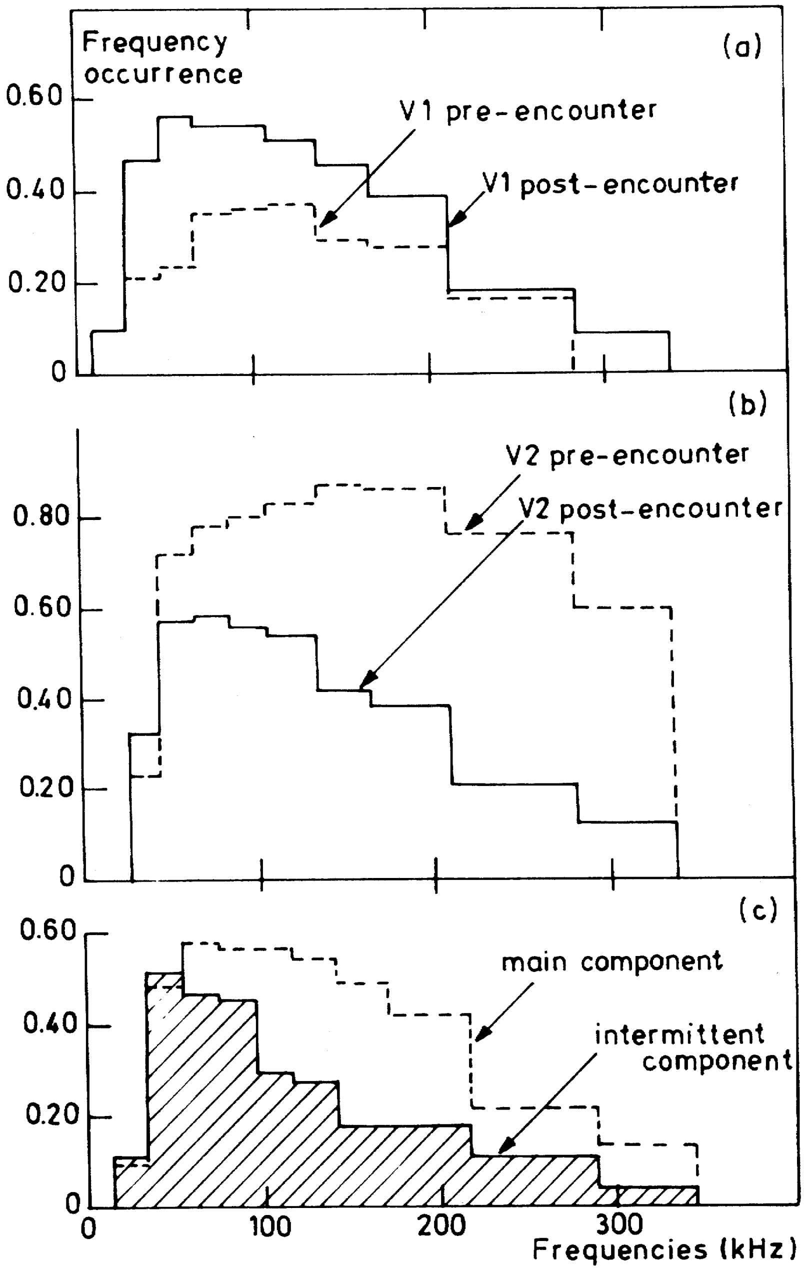

Figure 8: Frequency occurrence of the bKOM. Within a distance range we have plotted the number of rotations where the emission occurs at a given frequency. a) V1 pre– and post–encounter observations for the main component. b) V2 pre– and post–encounter observations for the main component. c) V1 post–encounter observations for the main and the intermittent component.

- At latitude less than or equal to 5°, there are fewer emissions observed in the high frequency range ($f > 200$ kHz). This is true whatever the distance of the spacecraft from Jupiter. The peak of frequency occurrence is between 60 and 120 kHz.

3.2 Polarization

The polarization response of two crossed monopoles has been investigated by Ortega–Molina and Daigne (1984) and applied to the PRA experiment. The apparent degree of circular polarization (P_c) measured by two short orthogonal monopoles is given by:

$$P_c = \frac{\text{LH - RH}}{\text{LH + RH}} = \frac{2\cos\tau}{1+\cos^2\tau} \times \frac{v}{1 - q\dfrac{\sin^2\tau}{1+\cos^2\tau}} \, .$$

where τ is the angle between the source direction and the normal to the electric plane, q and v are the two Stokes parameters. τ is related to Θ (the angle between the source direction and the normal to the plane of the monopoles) and Θ_c (the critical value of Θ where the Jovian emission would appear unpolarized) by the relation:

$$\tau = \Theta - \Theta_c + \frac{\pi}{2}$$

Then for small values of $\Theta - \Theta_c$

$$P_c \cong -2\sin(\Theta - \Theta_c) \cdot \frac{v}{(l-q)}$$

The sense of the apparent circular polarization reverses when the source direction is in the electric antenna plane (for $\Theta \cong \Theta_c$) whatever the linear component of the wave polarization. Moreover, P_c is proportional to $(\Theta - \Theta_c)$ in this angular range as long as the Stokes parameters of the wave are constant. From the design of the PRA polarizer the measured sense of circular polarization is that of the incoming wave for acute τ, therefore for $\Theta < \Theta_c$.

In the low frequency range (500 kHz to 1.2 kHz) the critical angle Θ_c has not been carefully investigated before V1 and V2 launches. To determine this value we have measured P_c at different periods of V1 and V2 observations when Θ varies 65° to 87° before encounters. The wave appears unpolarized at $\Theta_c = 70° \pm 3°$ (Fig. 9). In Figures 10 and 11 are plotted, for V1 and V2, the angles Θ for the periods of observation reported here.

- V1 spacecraft (Fig. 10): before encounter from 780919 to 790201, $\Theta > 70°$. Therefore the apparent sense of polarization, left–handed, is opposite to the correct one. From 790220 to the encounter, and after encounter to 790404, $\Theta < 70°$, the apparent sense of polarization, right–handed, is the correct one. After this date ($\Theta > 70°$) the observed sense is reversed (left–handed) and is therefore opposite to that of the radio wave. The result is that, before encounter, the wave is righthand polarized and after encounter it is still right–handed.

- V2 spacecraft (Fig. 11): before encounter and until 790310, $\Theta > 70°$. The apparent sense of polarization is left–handed and is therefore opposite to the correct one. From 790310 to the encounter, $\Theta \geq 70°$ the emission is unpolarized or weakly left–handed. Two or three days before encounter, $\Theta < 70°$, the observed polarization is right–handed: it is the correct one. After encounter, Θ is much greater than 70° and the apparent sense of polarization, left–handed, is opposite to the correct one.

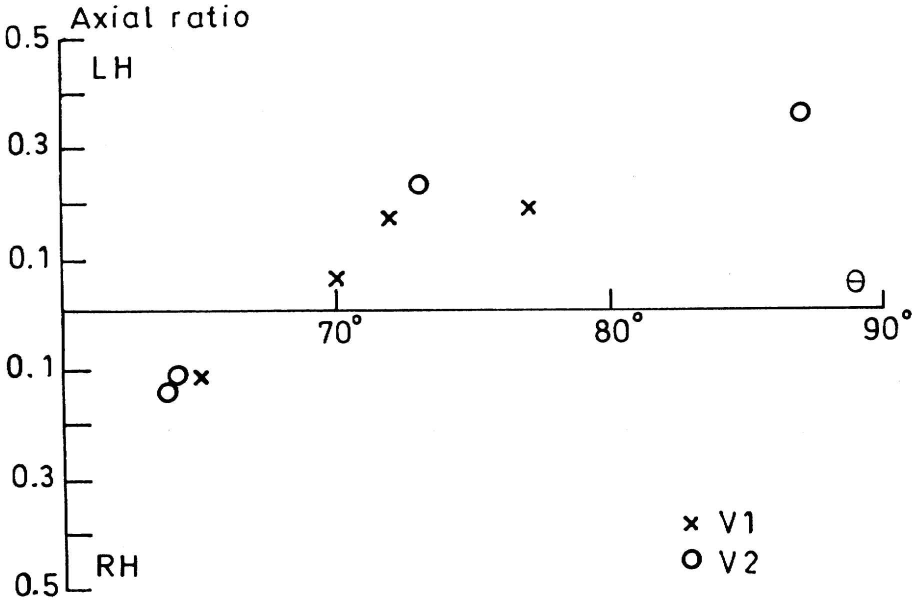

Figure 9: Measurements of the degree of polarization for V1 and V2 pre–encounter observations. At $\Theta = 70°$ (angle between the source direction and the normal to the monopoles) the Jovian emission appears unpolarized.

The result is that before <u>a</u>nd after encounter the wave is right–hand polarized and this is in contradiction with the results given by Desch and Kaiser (1980) or Alexander et al. (1980). These authors have not stated precisely which Θ_c value they did consider. Indeed, if this value were taken to be equal to 90°, then the apparent polarization before encounter (left–handed) would be taken as the correct one. But in, this case, one should observe a smaller degree of polarization at $\Theta = 85°$ than at $\Theta = 70°$. Our measurements show that there is a systematic increase of the degree of polarization from $\Theta = 70°$ to $\Theta = 85°$ (Fig. 9) for V1 as well as for V2 observations. Moreover the observed reversal of polarization between $\Theta = 65°$ and $\Theta = 85°$ could not be explained if $\Theta_c = 90°$.

3.3 The Intermittent Emission: (Fig. 3)

This emission is called intermittent since it is only observed from time to time. It is distinguished from the main emission because it is polarized in the opposite sense and it occurs in different ranges of longitude.

- Occurrence in CML: In Figures 6 and 7 the shaded areas represent the emission of opposite polarization to which the intermittent emission is associated. This compo-

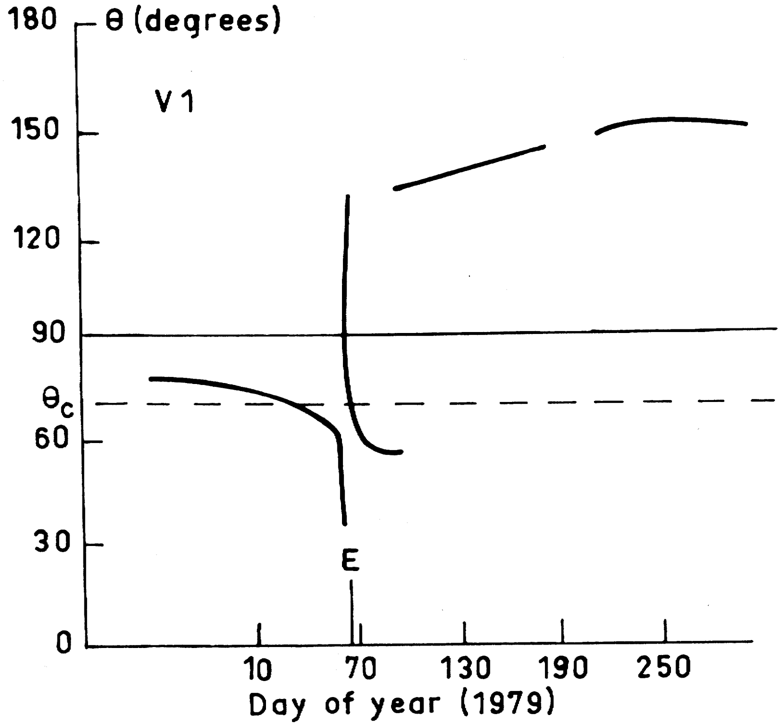

Figure 10: Variations of the angle Θ *between the source direction and the normal to the monopoles.* $\Theta_c\,(70^\circ)$ *is the angle where the sense of polarization of the Jovian emission reverses. The sense of the apparent polarization is the same as the incoming wave (RH) only for* $\Theta < 70^\circ$*, this is in the vicinity of V1 encounter. For most of the cruise* $\Theta > 70^\circ$ *the apparent polarization is opposite to the real one. Before and after encounters the main emission is RH polarized and the intermittent LH polarized.*

nent is more frequently observed after encounters where it occurs mainly at 0° – 90° and 330° – 360° CML. Before encounter this emission is not seen on V2. We notice that at great distances from Jupiter (Fig. 6) the occurrence of the intermittent emission is more scattered in longitude.

- Frequency range of occurrence of the intermittent emission: The sporadic emission is, most of the time, emitted in the range of 40 to 80 kHz as is shown in Figure 8c. However, from time to time the emitted frequencies go up to 480 kHz and in this case we find again the V–shaped envelope, typical of the main emission.

- Polarization of the intermittent emission: The emission is polarized in the opposite sense of the main emission and this property has allowed its identification mainly after encounters when the observed polarization is quite clear. On the other hand, in some cases, we have noticed that the polarization in the high frequency range is reversed with respect to the low frequency range and this occurs statistically at 100 kHz.

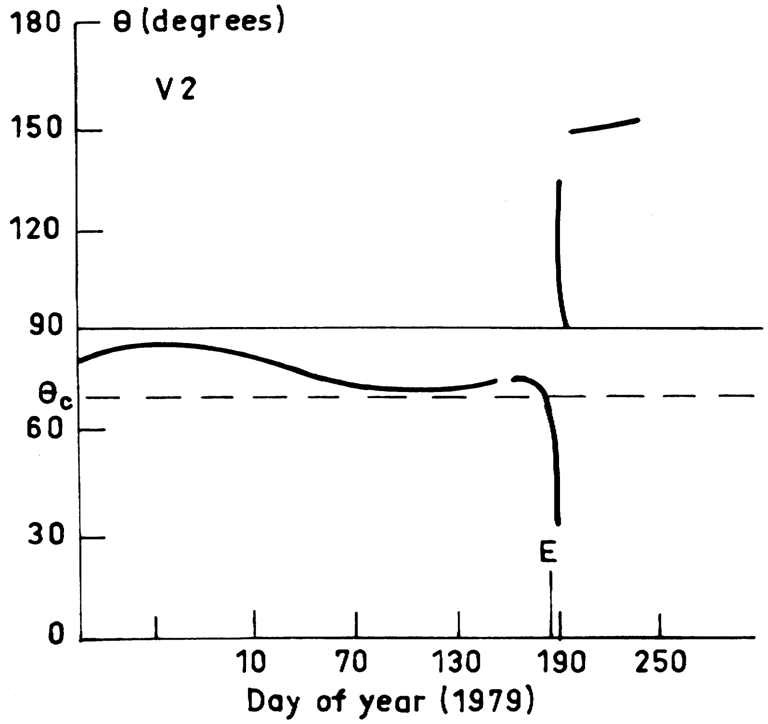

Figure 11: The same as Figure 10 but for Voyager 2.

4 Source Model

4.1 Argument for a Rotating Source

One of the main properties in the occurrence of bKOM is its strong dependence on the CML of the observer. This is very clear on the occurrence diagrams of V1 and V2 after encounter: the main peak is at 140° for both spacecraft whereas their local time differs from 75 min, (or 20° CML). If the emission source were fixed in local time, as considered by Desch and Kaiser (1980), the peak should be displaced in longitude from one observer to the other. The same would apply before encounters even if the occurrence diagram has a broader maximum. This property shows that we have to consider an emission beam rotating with the planet (and its system III reference frame) like a "light house" rather than a source fixed in local time.

4.2 Emission Mode

Polarization measurements have shown that the main emission is right–handed when seen from the Northern magnetic hemisphere, and that the intermittent emission is left–handed when seen from the Southern magnetic hemisphere. This is in agreement with an emission in the extraordinary mode. Since the observed polarization is unchanged when viewed from both day and night hemispheres, then we always observe the forward lobe radiation.

The X–mode has been ruled out by Desch and Kaiser (1980) because they considered a source fixed in local time and had to explain a polarization reversal before and after encounter. We have shown that a fixed source is not in agreement with the occurrence diagram of V1 and V2 and that the wave is right–hand polarized before and after encounter. Green and Gurnett (1980) have investigated the refraction of ray paths from a source near Jupiter in the O–mode. In their model the latitudinal boundary limit of the shadow–zone created by the torus increases with decreasing frequencies, from about 0° at 800 kHz to $\sim 12°$ at 56 kHz. But the comparison of V1 and V2 observations does not favour this result since at a lower declination (V1 at 3°) the higher frequencies are more occultated (Fig. 8).

4.3 Localization and Emission Beam of the Sources

Let us consider that the emission orginates just outside the cut off surfaces for the X–mode (Fig. 12). Green and Gurnett (1980) computed such contours from a combination of the models proposed by Sentman and Goertz (1978), Warwick et al. (1979a) and Franck et al. (1976). Two models of bKOM can be investigated for the rotating lighthouse:

- a source on a particular field line beamed into a hollow conical sheet whose axis coincides with the magnetic field line (like it is supposed for the decametric source).
- a source all around the planet beamed into a hollow conical sheet whose axis coincides with the magnetic dipole of the planet.

In the first hypothesis, we may consider a particular field line on the shell L = 6, the source being at the intersection of the field line with the cut off surfaces for the X–mode. In this case the beaming in the low frequency range will be mainly produced by the Io torus creating a shadow zone in the vicinity of the magnetic equator. Since the magnetic latitudes (δ_M) of the two spacecraft were in the range (-5°, +18°), the observations will be dominated by propagation effects through the Io torus. In the case of an emission in the X–mode and a source on the field line L = 6, the lowest radiated frequency would be about 80 kHz (Fig. 12) as has been noticed by Green and Gurnett (1980) and the radiation has been detected to as low as 10 kHz. Moreover there is no strong argument to consider a particular field line for the source since bKOM emission does not show any Io control (Desch and Kaiser, 1980).

In the second hypothesis, we consider the cut off surfaces for the X–mode. They have a particular shape in the vicinity of the magnetic equator due to the Io plasma torus. At a given frequency a “hollow” appears behind the torus. It is suggested that the source could be within this hollow all around the planet. We note that an increase of electron densities with energies greater than 160 keV at 5 R_J has been reported by Fillius and McIlwain (1974).

If the source were within this hollow the emission would be strongly beamed into a conical sheet whose axis is the magnetic dipole of the planet (Fig. 13). For low magnetic latitudes, the observer will be in a shadow zone due to the Io torus. In this model the beaming of the emission is essentially in magnetic latitude, but due to the tilt angle of the magnetic

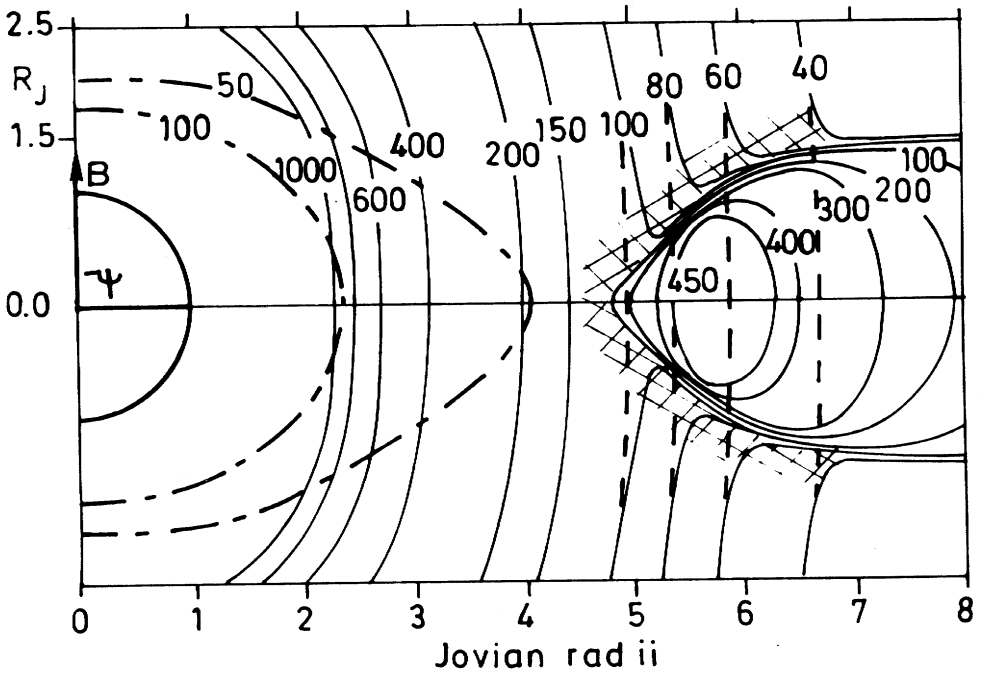

Figure 12: Contours of the cut off frequencies f_X for the X–mode in the Jovian magnetosphere in kHz (full line). Between the planet and the torus the f_c contours are identical to the f_X contours. In the torus f_c contours are shown by dashed lines. Two plasma frequency contours are also shown near the planet (dot–dashed line); in the torus f_p is nearly identical to f_X The bKOM source location in the Northern and Southern hemispheres is indicated by cross–hatched areas.

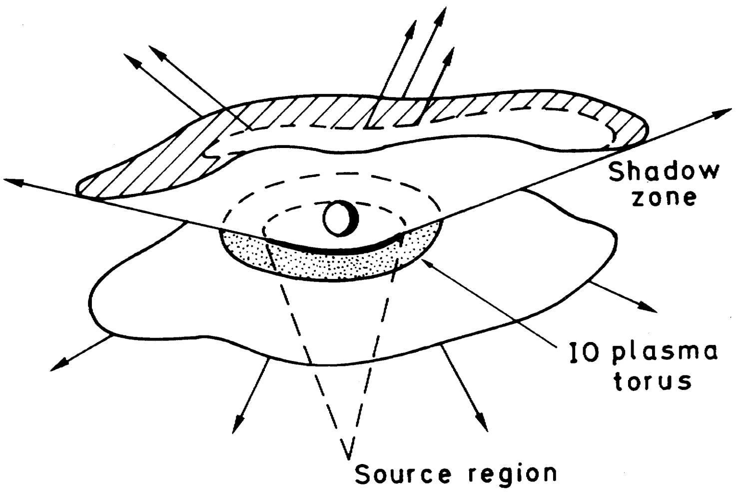

Figure 13: The beaming of the emission in zenomagnetic latitude and the shadow zone resulting from the Io plasma torus (after Kurth et al., 1980).

dipole a fixed observer will be swept by the beam only for a few precise ranges of CML. Therefore the conical sheet would whirl like a solid body and the observed pattern will have to be dependent on the latitude of the observer and not on its local time. In fact the difference observed in the CML occurrence diagrams for the two spacecraft, before and after the encounters, suggest that the beaming is different on the day and night side of the planet.

4.4 Consistency of the Model with the Observations

On the day side a broad maximum in the occurrence diagram at CML $\sim 200°$ suggests a thick conical sheet for the beaming. In Figure 14 we have represented the variations in magnetic latitude of V1 and V2 and the model for the emission beam, this model allows to explain the main results for V1 and V2 observations:

- The occurrence diagram in CML is easily explained with a uniform beam all around the planet for the Northern and Southern sources. The maximum of the main component at CML $\cong 200°$ corresponds to the maximum in magnetic latitude of the observers. At low magnetic latitude neither source is observed. From the width of the occurrence diagram we have been able to estimate the magnetic latitude of the boundary at 78 kHz, and we find that it is about 11°. In the Southern hemisphere the highest magnetic latitude is reached by V1 ($\delta_M = -8°$) at CML = 0°–90° and 300°–360°. If we admit that the boundary of the magnetic latitude of the Southern source is similar to that of the Northern source, this component should be observed neither by V1 nor V2. In fact it is observed very rarely and only by V1. This will be discussed in the next section.
- The difference in the occurrence probability for V1 and V2 observations is explained by the difference of the latitude of the observers. At a higher latitude the observer is swept by the Northern emission beam at each Jovian rotation for a longer period of time (Fig. 14a), The result is that the average occurrence probability of bKOM is higher and the width in CML of the occurrence peak is larger as has been observed (Fig. 14b and c).
- The typical V–shaped envelope of each bKOM event and the statistics on the emitted frequencies for different latitudes are due to the same phenomenon. Indeed, there is a frequency dependence of the lower limit of the emission beam since the latitude of the occultation boundary increases with increasing frequencies: for a high magnetic latitude of the observers all frequencies are observed, as the magnetic latitude decreases the highest frequencies are occultated by the Io plasma torus. In fact the highest frequencies are only observed at CML $\cong 200°$ (Fig. 2 and 3) that is at the highest magnetic latitudes of the observer; on the other hand the diagrams of the frequency occurrence (Fig. 8) show a greater occultation in the high frequency range for V1 observations (3°) compared to V2 observations (7.9°).

On the night side, the occurrence diagrams show two peaks in CML, one at 140° and a broader one at 240°. If we consider for the beam at a given frequency a hollow conical

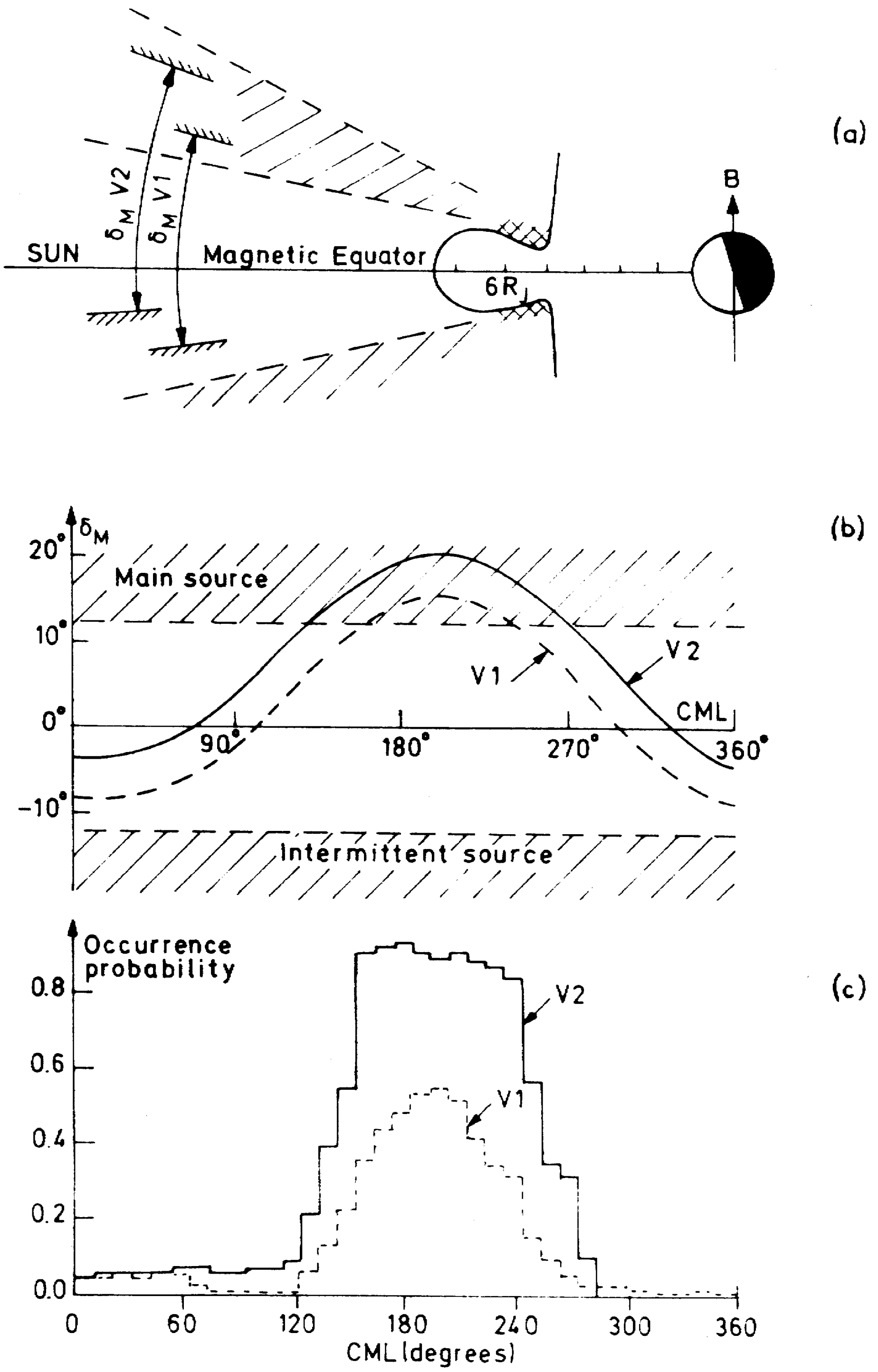

Figure 14: The source model on the day hemisphere. a) Beaming of the emission in a meridian plane at a given frequency, the source being at the inner boundary of the Io torus. b) A fixed observer (V1 or V2) will be swept by the beam only for given ranges of longitude (CML) due to the tilt angle of the magnetic dipole. c) The occurrence probability of the bKOM for V1 and V2 pre–encounter observations. The deduced low boundary of the beam is 11 for the main source.

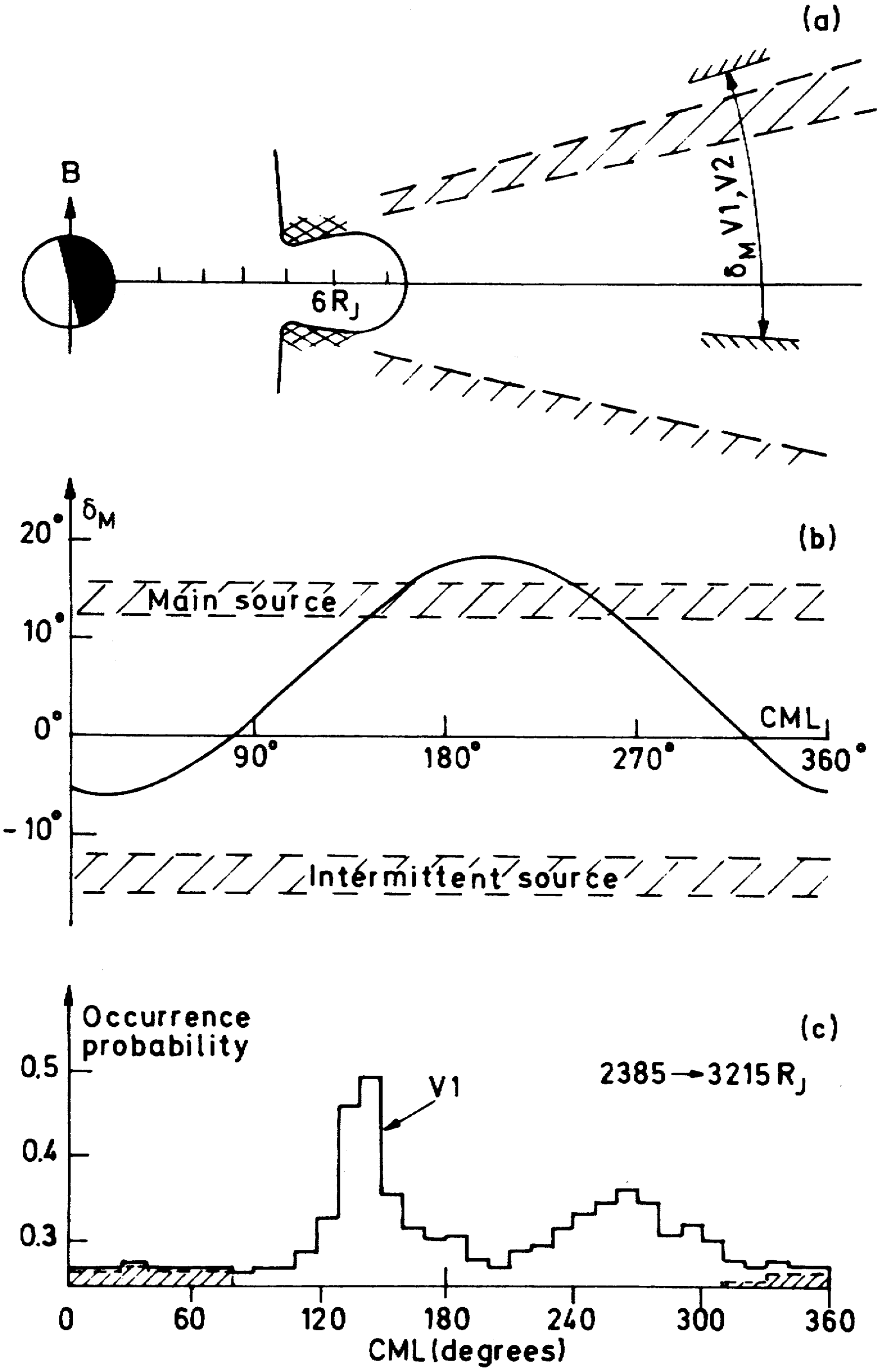

Figure 15: *The same as Figure 14 but for the night hemisphere observations. It is admitted that the beams are thinner than on the day side hemisphere. The observers would be swept two times by the beam of the main source during one Jovian rotation. The intermittent source would be observed by the spacecraft when the beam orientation changes and comes closer to the magnetic equator.*

sheet thicker on the night side than on the day side, it will sweep the observers two times during one rotation of the planet at symmetric longitudes with respect to 200° CML. Figure 15 shows how the beam could be crossed at 140° and 240° which are the peak positions in the occurrence diagrams after encounters. These longitude ranges correspond to a cone sheet between 11° and 14° of magnetic latitude, at 78 kHz. After encounter the Southern source should be observed by neither spacecrafte since the highest magnetic latitude reached is equal to - 6°. However, this source is observed a few times by the two observers. This is discussed in the next section.

4.5 Solar Wind Effects

We have noticed that the duration and the enitted frequencies of a bKOM event vary from one rotation to another (Fig. 4). In general when the duration of an event lasts a few hours ($\sim$ 150° of longitude), it is observed at all frequencies as if the magnetic latitude boundary of the beam were closer to the magnetic equator. For the same reason the Southern source could be observed from time to time when the cone sheet comes to a smaller magnetic latitude and sweeps the observers. In this case the source will be observed at CML $\sim$ O° – 90° and 300° – 360°. On the other hand there will be no observed emission when the beam boundary becomes greater than the magnetic latitude of the observers.

These temporal changes in the direction of the beam could be due to the source location or to variations in the shape or the height of the Io torus. From Figure 12 it is easily seen that the beam orientation is very dependent on the electron density in the inner region of the Io torus. These fluctuations seem to be induced by very large density variations in the solar wind as it will be shown in another study (Leblanc and Barrow, 1984).

5 Conclusion

The principal results of the average statistical properties of Jupiter's bKOM emissions can be summarized as follows: bKOM emission consists of two components which are polarized in the opposite sense. The main component observed regularly at most of Jovian rotations is right–hand polarized before and after encounter. The intermittent component observed only from time to time is left–hand polarized. We have shown that the occurrence of bKOM is dependent on the CML of the observers. The main component occurs in the range of 120° to 240° and the intermittent cornponent in the range of 0° – 90° and 330° – 360°. This property is in contradiction with an emission source fixed in local time.

The other properties of the bKOM concern the probability of occurrence and the frequency spectrum of occurrence which are strongly dependent on the observer's latitude. At the highest observer latitude the occurrence probability is very high and the frequency spectrum of occurrence is nearly constant between 60 and 300 kHz. At the lowest observer latitude there is an important decline of the occurrence probability and a peak of frequency occurrence at 80 kHz.

These results are interpreted in terms of a rotating source model and an emission in the X–mode. We have considered two sources localized all around the planet, behind the Io torus in the Northern and Southern hemispheres. The radiation is beamed at a given frequency as a hollow conical sheet whose axis is the magnetic dipole of the planet. With this model we are able to explain all the properties of bKOM emission: occurrence diagram in CML emitted frequencies and occurrence probabilities for the different observers latitudes. The differences in the occurrence diagrams for day–side and night–side observations are explained if the conical sheet is thicker on the day–side than on the night–side. From the width of the occurrence diagrams we have estimated the magnetic latitude boundary of the beam at 78 kHz. On the day–side the lowest boundary is 11° and the highest is more than 18°; on the night–side the boundaries are between 11° and 14°. Fluctuations in the orientation of these boundaries imply that the occurrence, the duration and the frequency spectrum of bKOM emission vary with time.

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Discussion

Question:

You said something about the so–called “focusing effect” in controlling the bKOM emission. Can you explain the physical reasons how this focusing effect can work at far distances?

Leblanc:

The focusing occurs due to the existence of the Io torus. Then it is a matter of ray tracing.

Question:

In your conclusion you mentioned two longitudes for the nKOM emission. Is there no drifting in longitude?

Leblanc:

For the nKOM we did the same investigation as for the bKOM. The nKOM emission was observed for two or three sucessive rotations and we have found a shift in longitude. But the occurrence in Central Meridian Longitude is not uniform and then the hypothesis of a long–lived rotating source has to be reconsidered. An exhaustive study of this emission is to be published by Daigne and Leblanc (*J. Geophys. Res.*, 1985).