

EXTENDED GROUND-BASED OBSERVATIONS OF JUPITER'S DECAMETRIC RADIATION

Françoise Genova

*Observatoire de Paris, Section de Meudon
DASOP and UA CNRS 324
92195 Meudon Principal Cedex, FRANCE*

Abstract

Jupiter's decametric radiation is the only planetary radio emission that can be observed from the ground: it was discovered in 1955 from ground-based observations. Ground-based studies have proven to be quite complementary to spacecraft observations. The long term synoptic observations, which are still performed regularly, are essential to study the variability of Jupiter's emission, which is important to understand the internal and external controls of the emission (although the handling of the data set can be made difficult by the strong periodicities due to the Earth motion). On the other hand, the short variations of the emission can be properly studied from the ground only: the most complete informations are drawn from the dynamic spectra, recorded with high time and frequency resolution, which require large data transmission and storage capabilities. This also allowed to study the effects of the propagation of the emission through the inhomogeneous media between the source and the radio telescope, which also gave informations about the emission itself, leading for instance to the first observational study of the source position. Finally, the simultaneous use of ground-based and space data has proven to be a valuable tool to study, for instance, the emission directivity, and also the relationship between decameter and hectometer emissions. In the future, during the Galileo and Ulysses missions, which have radio receivers limited to the low frequency part of the Jovian radio emission frequency range, decameter data will be available from ground-based observations only.

1. Introduction

Radio observations from the ground are limited to frequencies above the ionospheric cutoff, which is in general of the order of 10 MHz (and can be as low as 2 – 3 MHz). It is thus not possible to observe the Earth's, Saturn's and Uranus' "auroral" kilometric radio emissions, nor the low frequency part of Jupiter's decametric radiation. All these emissions can be seen from spacecraft only, and were observed mainly by the radio receiver of the Voyager Planetary Radio Astronomy (PRA) experiment. The same experiment also allowed important observations of the Jovian decametric radiation, which complemented the large data set obtained from many years of systematic ground-based observations of these emissions.

In the following, the importance of the ground-based observations will be shown: the results deduced from ground observations alone, and from the complementary use of ground and space data, will be discussed. The main characteristics of the Jovian radio

emission is its large temporal and spectral variability: the observed timescales range from milliseconds to days, weeks and longer; patterns with an instantaneous frequency band narrower than a few hundred kilohertz are observed, whereas the total bandwidth of a storm can be larger than 20 MHz. It is then highly desirable to perform long term synoptic observations with a very good time resolution, on a large frequency bandwidth, with a good frequency resolution — which is somehow contradictory in terms of data acquisition and storage. The emission is so variable that, in general, it can only be studied by the way of statistics, which explains the importance of large data sets, and of the catalogs established from these data sets. Another possible statistical approach, for the study of the very fine structure of the emission, is beautifully illustrated by the atlas of the dynamic spectra recorded by Ellis in Tasmania with very good time and frequency resolution (Ellis, 1979).

Since its discovery in 1955 by Burke and Franklin (1955b), the Jovian decametric emission has been monitored by several instruments, some of them still being used for daily observations. Several catalogs have been published, all giving the times of occurrence of emission, with in general some characteristics of the observed events, in particular, in the case of spectral observations, the total frequency range of each emission episode, or even sometimes its dynamic spectrum. For instance, Thieman (1979) collected the fixed frequency observations from Florida, GSFC and Texas, from 1957 to 1978. In Japan, Oya and Morioka (1985, 1987) perform observations at fixed frequency and in the 17 – 30 MHz frequency range, at the Zao station. Two very large sets of observations, which cover the whole frequency range from the ionospheric cutoff to the highest observed emission frequency, about 40 MHz, were obtained from 1960 to 1975 at Boulder (Warwick et al., 1975) and from 1978 at Nançay, where daily observations are still going on (Boischot et al., 1980; Leblanc et al., 1981, 1983; Leblanc and Gerbault, 1988). Voyager observations can also be used for statistics of course, but in the decametric range for only about two months around the encounter of each spacecraft with the planet, due to a high level of interference (see e.g. Barrow's (1981) catalog, which has a form similar to the Boulder and Nançay ones).

The results deduced from the very large data set obtained from the ground will be discussed in the following. First, one will show how the different phenomena responsible for the long term variations of the emission (i.e., with time scales greater than a few hours) were found and studied from the long term synoptic observations of the emission. Then, the "short" variations of the emission, with time scales from one millisecond to a few minutes, will be described. Examples of the complementary use of ground-based and space data will then be given. Finally, the perspectives and needs will be discussed.

2. The long term variations of the emission

The long term synoptic observations of the emission allow one to study the long term variability of the emission. The two dominant periodicities of the emission (Figure 1), the period of rotation of the planet and the orbital period of Io (Bigg, 1964), have long been recognized from ground-based observations, and will be discussed in this paragraph. The study of the effect of the solar wind on the Io-independent emission is extensively dealt with by Barrow elsewhere in this book. We simply recall here that it was first recognized from ground-based data. The study was particularly difficult because of interfering periodicities due to the Earth motion, and because it is not easy to extrapolate reliably solar wind data measured within the Earth's orbit outwards to Jupiter's position. The existence of this effect was still controversial (see e.g. the review by Carr et al., 1983), when it was studied again from radio and solar wind observations from Voyager, which are free from the above mentioned difficulties, and which confirmed the previous results. The exact mechanism of this solar wind control is not well understood, but its existence means that the solar wind fluctuations are felt, although probably not directly, in the source region of the Io-independent emission. Finally, the latitudinal directivity of the emission, which produces long term fluctuations of the emission while the Earth moves with respect to a Jupiter-centered frame, was, like the solar wind effect, studied both from ground and space observations, and will be discussed in the section dedicated to the illustration of the complementarity between the two kinds of observations.

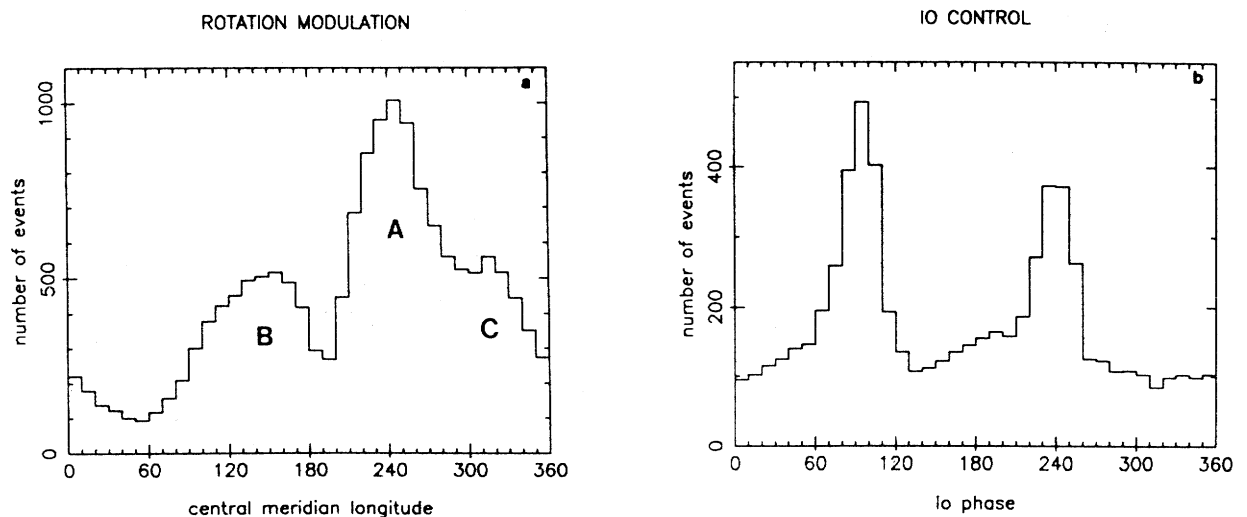


Fig. 1 (from Genova et al., 1988): Control by the planetary rotation and Io.

a. Modulation by the planetary rotation : Histogram of the emissions observed at Boulder from 1960 to 1975 (Warwick et al., 1975), and at Nançay from 1978 to 1984 (Leblanc et al., 1981, 1983; Leblanc and Gerbault, 1988), as a function of the central meridian longitude. Two main peaks appear, the second one with two sub-peaks.

b. Io control : Histogram of the emissions observed at Boulder and at Nançay during the same periods, as a function of the Io phase.

The emission is primarily organized with respect to the Jovigraphic longitude of the observer (Central Meridian Longitude, or CML), i.e. to the observer's position in the planetary magnetic field (Figure 1a): the most precise estimations of the rotation period of the core of the planet, $9\text{ h }55\text{ min }29.71\text{ s} \pm 0.01\text{ s}$, is deduced from synoptic observations of the decameter radiation over long periods of time (Carr et al., 1970; Duncan, 1971; Kaiser and Alexander, 1972; Alexander, 1975; Riddle and Warwick, 1976; May et al., 1979). In fact, the value of the magnetic field at the source controls the emission frequency, which is probably very close to the local gyrofrequency (f in MHz $\sim 2.8 B$ in gauss). While the planet rotates, the position of the observer changes in the emission pattern, producing the observed periodicity in the emission. In particular, emissions at relatively high frequency (above ~ 28 MHz) can be emitted only in the small region, close to the surface in the northern hemisphere, where the local gyrofrequency reaches sufficiently high values (deduced from the Pioneer magnetic field models (Acuña et al., 1983) see e.g. Figure 5 of the paper by Aubier et al. (1988) in this book). With emission beamed in a hollow cone centered on the local magnetic field direction (behaving like a corotating "searchlight beam" – Maeda and Carr, 1984; Riihimaa, 1986), the two lobes of the cone emitted in this region pass successively in front of the observer during one planetary rotation, producing the two occurrence peaks in Figure 1a.

The planetary rotation modulates the whole emission. On the other hand, some emissions depend on the observer's position with respect to Io's direction, while others do not. The Io-dependent emissions occur at certain Io phases (Figure 1b — the angle between the opposite to the direction of observation and Io's direction seen from Jupiter), are more intense than the others (Desch et al., 1975; Desch, 1980), their global dynamic spectra have specific shapes (Dulk, 1965, see also Boischot et al., 1981, for Voyager results, and the examples shown in Figure 3 of the paper by Aubier et al. (1988) in this book); Io also controls the occurrence and/or shape of some of the fine structures of the emission, as it will be shown below. The existence of the Io control has long been thought to indicate that the source of the Io-dependent emission is very close to or along the Jovian magnetic field line which intersects Io. The Io control can be understood, for instance, if there is a population of energetic particles, with characteristics suitable to trigger the emission, produced by Io — maybe by Alfvén waves due to Io's motion in the planetary magnetic field (Goertz, 1980; Neubauer, 1980; Acuña et al., 1981). One can also think that the presence of Io simply enhances particle precipitations (see e.g. Winglee, 1986; see also the discussion of the location of the source of the Io-dependent emission by Genova, 1985, and Aubier et al. (1988) in this book).

All these statistical studies of the modulation of the emission were made possible by the use of long term synoptic observations, however one must keep in mind that it is necessary to be very careful when handling this kind of data. For instance, there is a one-week period in the ground-based data, due to beats between the periods of Jupiter, Io and the Earth (see e.g. Sastry, 1968). Moreover, when the control of the emission by the planetary rotation and Io is studied, one must take into account the non-uniform coverage of the widely used Central Meridian Longitude – Io phase plane, even for very long term observations (Figure 2 – this is still worse in the case of space observations,

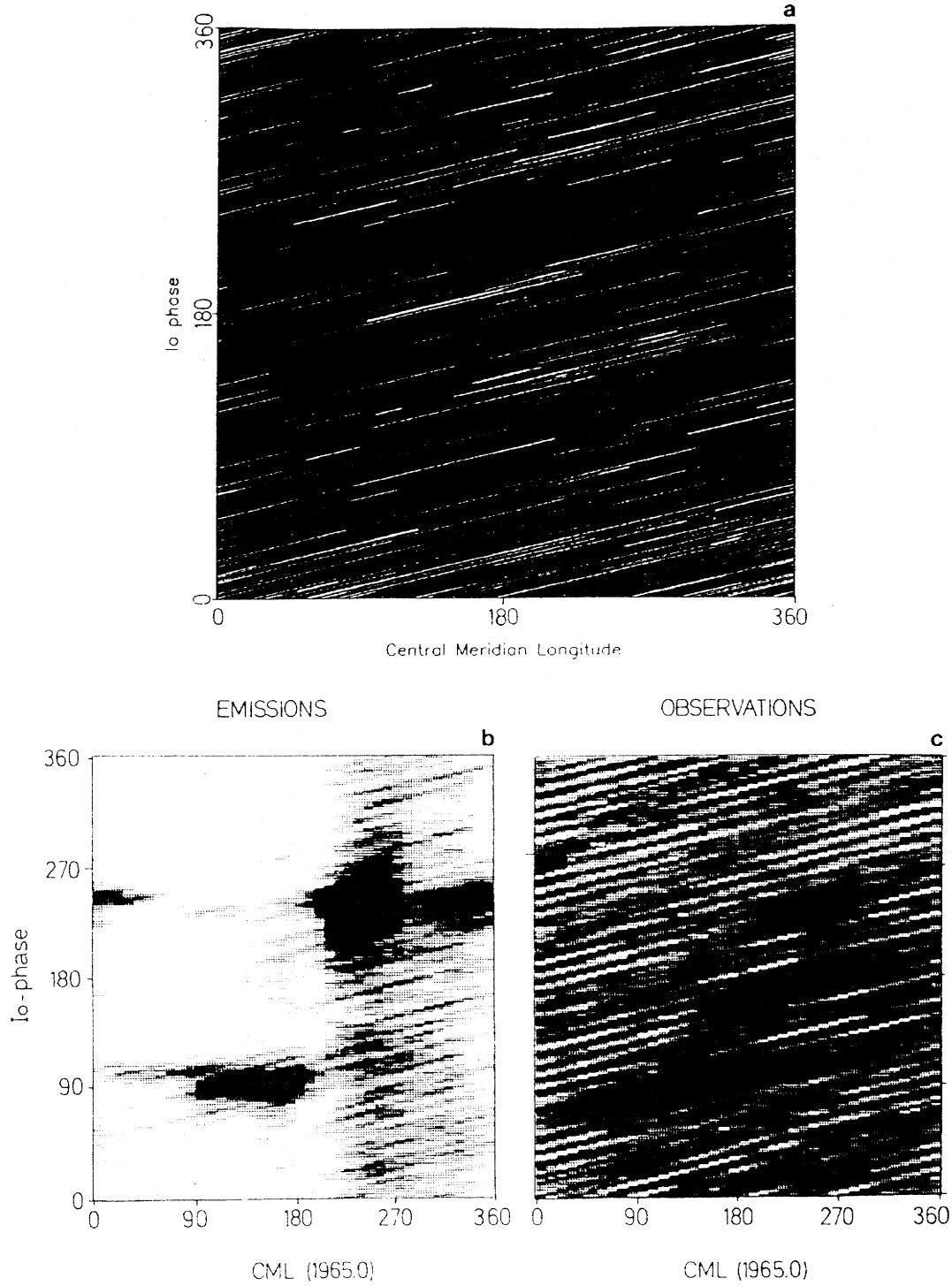


Fig. 2 (from Genova et al., 1988): Non-uniform coverage in central meridian longitude and Io phase. The Nançay plot (2a) shows the tracks of Nançay observations from 1978 to 1984. Figures 2c, b show the observations and emissions observed at Boulder from 1960 to 1975, in grey levels. White regions were observed less than 30 times, black regions more than 60 times. Note that in particular, the structures found in the non-Io-A region (for CML $\geq 200^\circ$) are artifacts due to unequal coverage by the observations, except for the Io-A region (for Io phase between 180° and 270°).

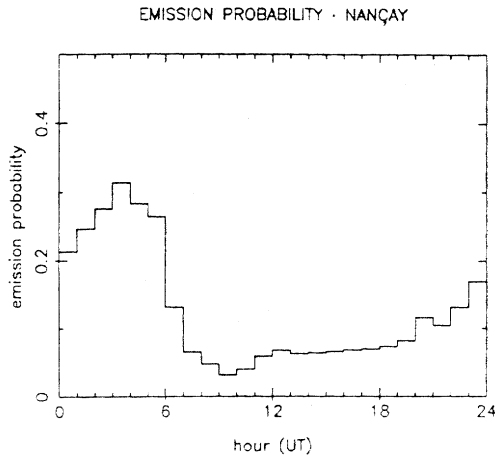


Fig. 3 (from Genova et al., 1988): Probability of observing an emission at Nançay, function of the hour in day. Very few emissions are observed during daytime.

which cover much shorter periods of time). Finally, which is more specific to Earth-based observations, the conditions of observations, in terms of interference level and ionospheric transmission, are different during day and at night (Figure 3), and also vary with the season. All this can introduce fictitious periodicities or variations, which must be systematically searched for in this kind of studies and are easier to detect when the data set covers a sufficient period of time.

3. Study of the fine structure of the emission

The high time and frequency resolution necessary to study the fine structure of the emission requires large data acquisition and storage capability, during periods of time long enough to be able again to perform statistical studies. If one remembers that the time resolution of the most widely used mode of the Voyager PRA experiment is 12 s, and that only a few months of Voyager observations are usable in the decametric range, it appears that ground-based observations are a very privileged tool here, especially to study the fluctuations with time scales of or less than a few seconds, but also the longer ones, since the data sets acquired from the ground are larger. Note also that it is much easier to design and build rapidly an apparatus needed to study a specific problem, to be used in a ground station, than for space observations (this was done for example by various groups to study the S-burst drift rate). In the following, the importance of ground-based observations for the study of the different modulations with time scales shorter than a few minutes is discussed.

The arcs, with a time scale of a few minutes and a very large total bandwidth, are typically within the reach of space observations: Voyager observations showed that arc patterns compose most of the emissions, and allowed to describe their properties (Figure 4; Boischot et al., 1981; Leblanc, 1981). But the upper leg of the arcs is well seen in dynamic spectra obtained from the ground (Figure 5), which could give access to studies of a larger number of cases (remember that only a few months of Voyager observations can be used

at decameter wavelengths), and could allow to study their fine structure, which seems sometimes much more complex than can be seen from looking at Voyager data.

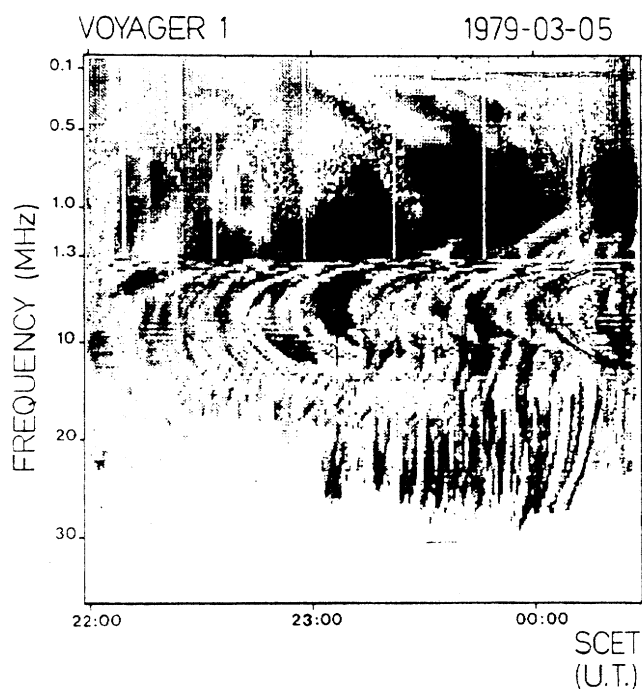


Fig. 4 (from Boischot et al., 1981): Dynamic spectrum observed by Voyager, showing the arc patterns which make up most of the emission. The two different frequency bands (below and above 1.2 MHz) correspond to the two Voyager receivers.

The shortest timescales of the Jovian decameter emission correspond to the S- (or millisecond) bursts (Figure 5a, c). The S-burst emission is composed of bursts of duration ~ 10 msec, with an instantaneous bandwidth of a few hundred kilohertz, which drift rapidly in frequency and have a total bandwidth of a few MHz. Nearly all the studies of S-bursts were done from the ground: some of them simply used statistics of occurrence of S-burst storms, or studied the global dynamic spectra of such storms, as it appears for instance on Figure 5b or 5c, to compare with the properties of the more usual smoother emission (Figure 5a, c). Others used more specific experimental apparatus to study the fine structure of the bursts themselves (Figure 6). The first kind of S-burst studies showed that S-burst storms are always controlled by Io. Their occurrence in Central Meridian Longitude and Io phase is well studied (see e.g. Riihimaa, 1977; Leblanc et al., 1980b; Genova and Calvert, 1988; and also the study of Voyager observations below 15 MHz by Alexander and Desch, 1984): their occurrence regions in CML and Io phase above ~ 15 MHz are narrower than the ones of the "smooth" Io-dependent emissions. As explained by Aubier et al. (1988) in this book, it was shown by studying their high frequency limit that they come from the same source region as the smooth emission (Genova and Calvert, 1988). Their narrower occurrence in CML and Io phase then probably indicates that the S-burst emission is more directive than the smooth emission (at least above 15 MHz). Spectral observations with a large frequency range also allow to study the dynamic spectrum of S-bursts storms: from ground-based observations, it was shown that they

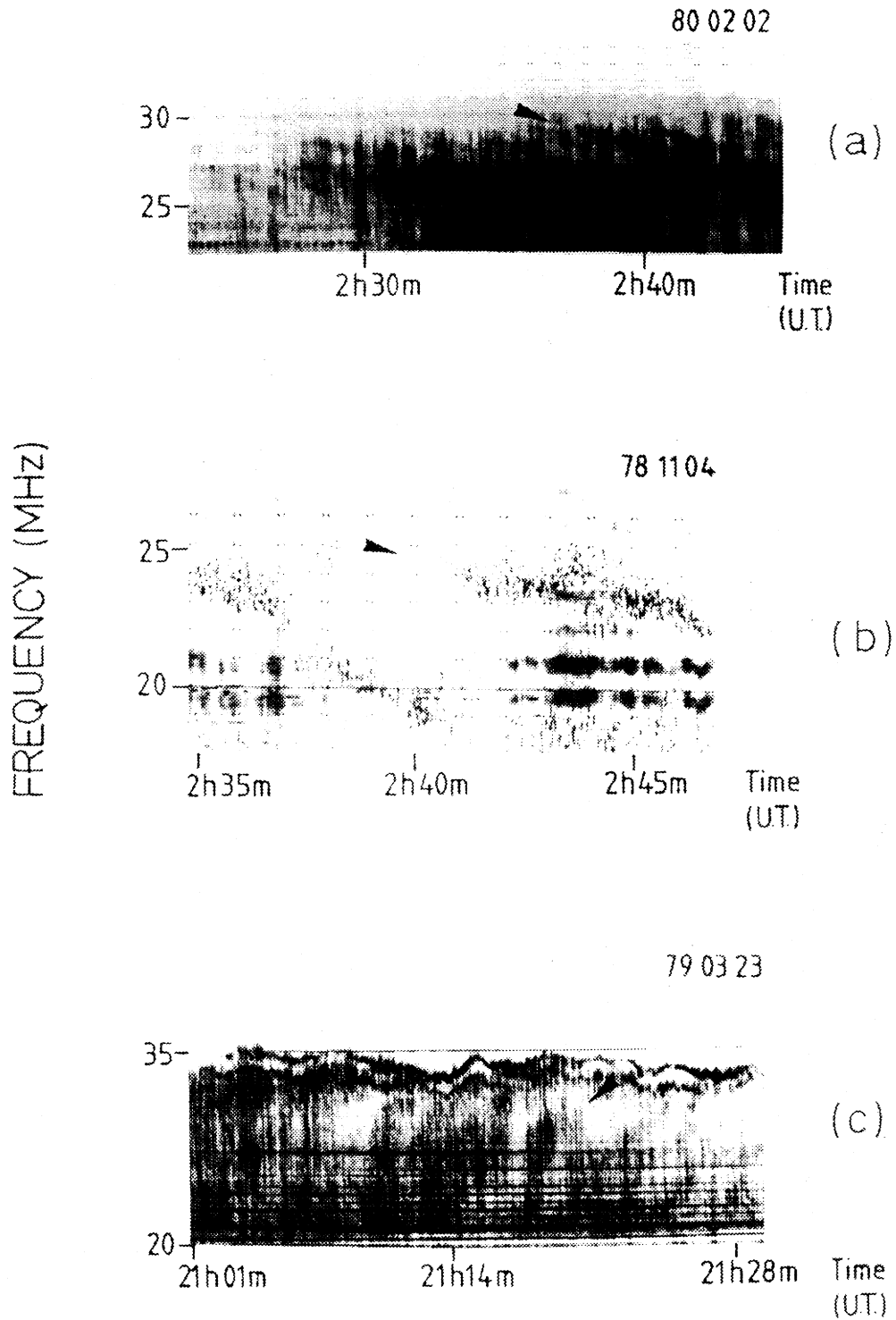


Fig. 5 (from Genova et al., 1988): Dynamic spectra of the smooth (Figure 5a) and S-burst (Figure 5b) emission observed at Nançay. Each dot on Figure 5b corresponds to a S-burst, through which the receiver sweeps rapidly. Smooth and S-burst emissions appear together on Figure 5c, with a splitting at the high frequency limit of the emission. The drifting patterns which correspond to the upper leg of the arcs are pointed at by arrows.

are organized in drifting patterns (Figure 5b — Leblanc et al., 1980b), which were later recognized, from Voyager data, as the upper leg of S-burst arcs, distincts from the arc pattern of the smooth emission (Leblanc and Genova, 1981). On the other hand, with experiments with very high time and frequency resolution, the spectrum of individual S-bursts is also accessible (Figure 6). Many examples of the fine structure of the emission at these timescales can be found in Ellis' atlas (1979), which shows that most (but not strictly all) S-bursts drift rapidly towards low frequencies. Many authors measured the S-burst drift rate: one possible interpretation is that it corresponds to the motion of the particles which trigger the emission, along magnetic field lines (the instantaneous emission frequency being the gyrofrequency at the source). Then the observed negative drift rates indicate that the particles are moving upwards, towards decreasing magnetic field. Measurements of drift rates at high frequencies (above about 27 MHz) showed that the particles cannot be trapped along the magnetic field lines, but are accelerated close to the northern ionosphere (Desch et al., 1978; Ellis, 1980; Leblanc et al., 1980a). The drift can be alternatively interpreted as a dispersion due to the emission mechanism itself (see e.g. Zaitsev et al., 1986), and in fact it is not yet clear whether the emission mechanism for S-burst emission is the same as the one of the smooth emission. One important parameter relevant to the emission mechanism is the S-burst polarization. Only preliminary results are available; they show that both senses of circular polarization are observed (Riihimaa, 1976 — from the ground; Alexander and Desch, 1984 — from Voyager), but more statistics are needed.

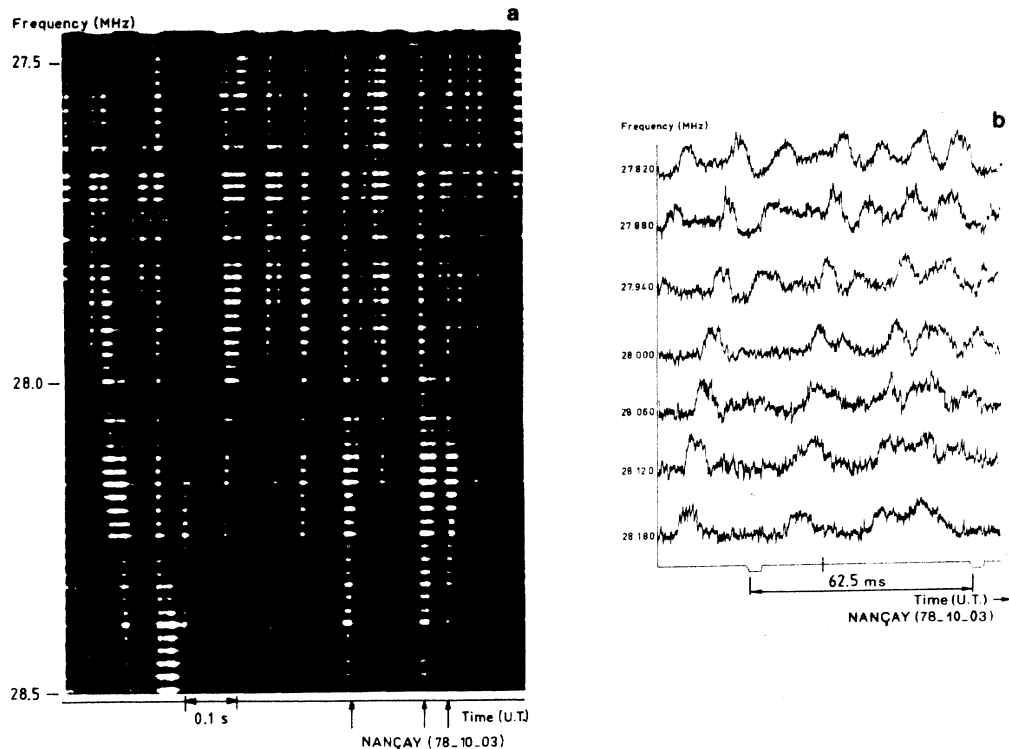


Fig. 6 (adapted from Leblanc et al., 1980a): High resolution dynamic spectrum (Figure 6a) and fixed-frequency intensity records (Figure 6b) of S-bursts, which were used to measure the frequency drift of the bursts.

Other types of modulations, intermediate between the S-bursts and the arcs, are also seen on ground-based observations only. Several of them have time scales close to one or a few seconds, and they can be recognized only on wideband dynamic spectra, on which their different characteristic patterns appear. Some of the modulations are produced close to Jupiter, and others are due to propagation of the emission between Jupiter and the radio receiver. They will be discussed successively in the following.

First, some kinds of modulation of the dynamic spectra certainly appear at or close to the source. Although they have sometimes been studied by several authors, there is no general agreement about their origin.

a. Modulation lanes : They are families of regular fringes, which appear very often on the dynamic spectra (Figure 7 — Riihimaa, 1970, 1974, 1976, 1979; Genova et al., 1981). Their instantaneous duration varies from a few seconds to a few ten seconds; they drift towards positive or negative frequencies, and are always curved towards the high frequencies. Their occurrence and sense of drift is controlled by the observer's position in longitude. Meyer-Vernet et al. (1981) interpreted them as fringes due to large scale diffraction in the Io-torus.

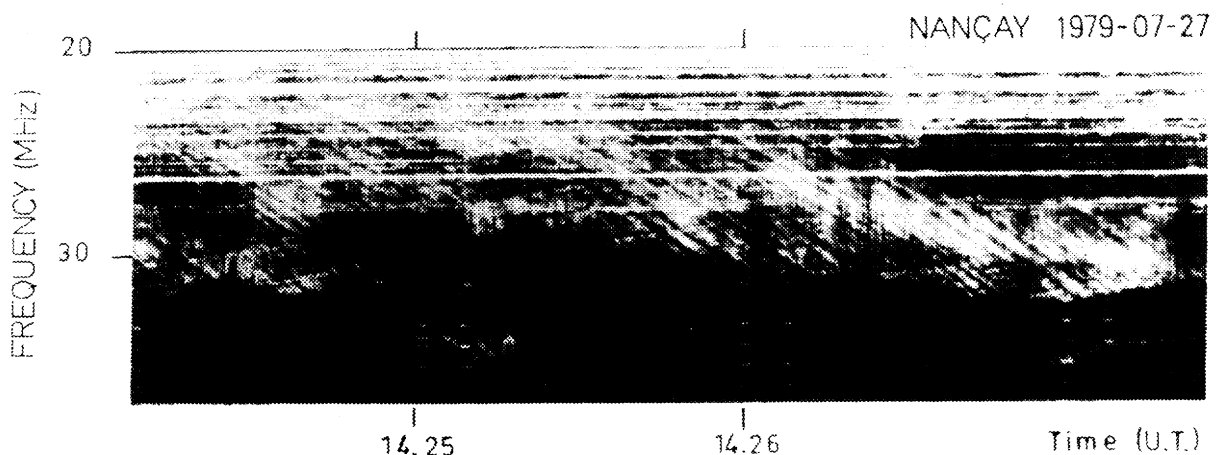


Fig. 7 (adapted from Genova et al., 1981): Modulation lanes.

b. Narrow-band (or N) bursts : They are bands of emission, observed with a high resolution by Krausche et al. (1976), Flagg et al. (1976), and Riihimaa (1977, 1985) on dynamic spectra with a relatively small total bandwidth. They look like trains of S-bursts. They are perhaps very similar to the "*splitting*" described by Leblanc and Rubio (1982), which appears on wideband dynamic spectra as bands of emission at the higher frequency limit of the emission (Figure 5c), and is strongly rotation and Io-controlled. The time resolution of the splitting observations has not been sufficient to decide whether the bands of emission have a fine structure similar to that of N-bursts.

c. High frequency lanes are relatively faint modulations which appear on the upper leg of arcs, and are rotation and Io-controlled (Genova et al., 1981). Their origin is unknown, perhaps linked to the formation of the arcs.

On the other hand, the different inhomogeneous media through which the waves propagate, between Jupiter's environment and the radio receiver on Earth, also produce characteristic modulations of the emission, which have been used to study the properties of these media, and/or those of the radio emission itself.

a. The interplanetary medium density inhomogeneities, which cross the ray path, convected in the solar wind, produce the *interplanetary scintillation* (IPS). These regular, ~ 1 -second modulations of the emission appear out of the periods of conjunction and opposition of Jupiter with the Sun, for elongations between $\sim 25^\circ$ and $\sim 160^\circ$ (Figure 8a — Douglas and Smith, 1967; Slee and Higgins, 1968; Riihimaa, 1978; Genova and Leblanc, 1981). They have been used to study the interplanetary scintillation properties, and also for the first study of the localization of the source of the Jovian decametric radiation (Genova and Boischot, 1981; Boischot et al., 1987; see also Genova, 1985).

b. Two types of modulation are produced by the Earth ionosphere:

- *Fringes*, which have durations of a few seconds to a few ten seconds (Figure 8b — Warwick, 1964; Riihimaa, 1979; Genova et al., 1981). Since they can be mistaken for modulation lanes, wideband dynamic spectra and long term statistics are needed to recognize them properly: at Nançay, they appear only at night in winter, and their wideband pattern is not exactly the same as the one of modulation lanes. They could be linked to the presence of spread-F in the ionosphere.
- *Caustic patterns* are due to the presence of medium scale travelling ionospheric disturbances (TIDs) crossing the line of sight, which play the role of a lens. They are thus seasonal, and appear in autumn and winter, like the TIDs themselves. First predicted by Meyer-Vernet (1980) and detected by Meyer-Vernet et al. (1981), their properties were studied by Genova and Aubier (1983) and Mercier (1986) (on solar dynamic spectra). Since the source of Jovian decametric emission is very small, diffraction fringes parallel to the caustic are also seen in the case of Jupiter's emission (Figure 8c). These decametric patterns have been used to study the properties of the TIDs.

4. Complementary use of ground and space data

A few results deduced from space observations of the Jovian radio emission have already been incidentally quoted in the previous sections. In the following, a few specific examples are detailed to illustrate better the complementary use of ground-based and spacecraft observations. Another good example could be the study of the solar wind effect on the emission (see above and Barrow's review in these proceedings).

4.1 Study of the emission directivity in local time and latitude

The beaming of the emission can be measured directly with simultaneous observations from different directions (Poquerusse and Lecacheux, 1978, made simultaneous stereo observations from Nançay and Stereo 5 at 30 MHz). On the other hand, it can be studied statistically only if observations from a sufficiently large range of directions with respect to the planet reference frame are available. Ground-based observations are limited to

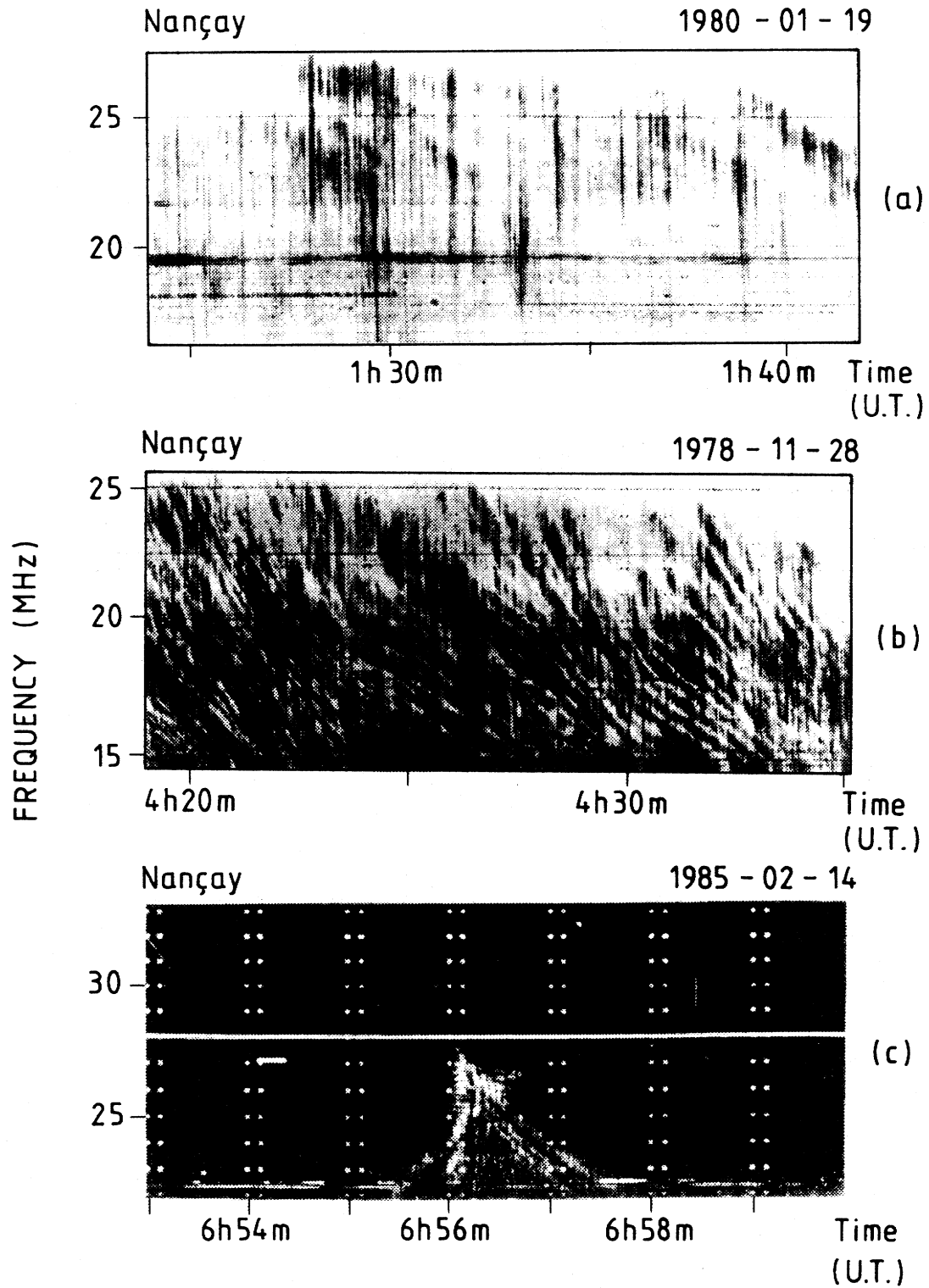


Fig. 8 (from Genova, 1987b): Effects of the propagation of the emission between Jupiter and the Earth, observed on dynamic spectra recorded at Nançay. Interplanetary scintillation produces the regular nearly vertical pattern on Figure 8a, ionospheric fringes and caustic are seen on Figure 8b and c, respectively.

small ranges in local time and Jovian declination, and there the space observations from Voyager have well extended the observed intervals. For example, the Earth is always very close to the direction of the Jovian noon. Voyager observations from the night and early morning side of the planet have shown that the dominant CML of occurrence of the non-Io emissions depends on the local time of observation, whereas this is not true for the Io emissions (Alexander et al., 1981; Leblanc, 1981 — it would probably be fruitful to try to interpret this important difference between the Io and non-Io emissions, perhaps in terms of comparison of the source location of the two types of emissions). Similarly, only a limited latitude range is observed from the ground (it varies by $\pm 3.3^\circ$ during the Jovian year). It has been possible however to show that the emission occurrence and properties vary with latitude, when observed from the ground (see e.g. Gulkis and Carr, 1966; Lecacheux, 1974; St Cyr, 1985). On the other hand, the beaming at lower frequency was studied from the morphology of the hectometer dynamic spectra observed by Voyager (Alexander et al., 1979b). Finally, the evolution of some dynamic spectra patterns with the Jovian latitude of the observer was studied from Nançay and Voyager observations (Figure 9 — Barrow et al., 1982). All this suggests a strong latitudinal beaming of the emissions.

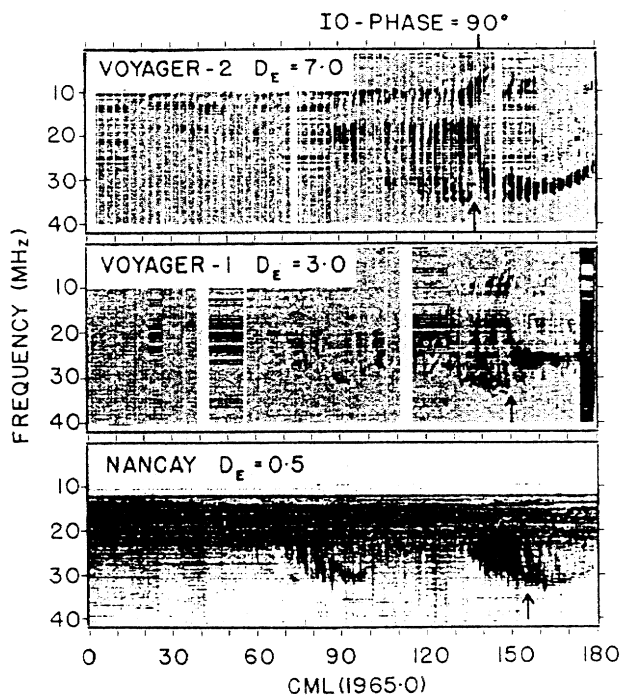


Fig. 9 (from Barrow et al., 1982): Dynamic spectra observed by Voyager and at Nançay with similar receivers, at the same CML and Io phase, for different values of the observer jovigraphic latitudes (D_E). The dynamic spectra are very similar, the position of the "gap" (arrows) depends on D_E .

4.2 Relationship between decameter and hectometer emission

Before the observations of the Jovian emission by spacecraft, it was simply known that the low frequency limit of the Jovian emission is below the ionospheric cutoff. Wideband spectral observations by Voyager gave the opportunity to study this limit better, but the problem was still not simple: the Voyager observations are performed by two receivers, both with linear frequency coverage, but with different characteristics, one between 1.2

kHz and 1.2 MHz, and the other between 1.2 MHz and 40 MHz (Figure 4). Several types of emission appear in the low frequency receiver. The Jovian broadband and narrowband kilometric radiations, which are in the kilometric range and have specific properties, are probably different from the decameter emission. The other one, the Jovian hectometric radiation (or HOM), was a good candidate to be the low frequency part of the decameter emission. But this was not easy to demonstrate, because of the different characteristics of the two receivers, and of interferences around 5 MHz in the low frequency part of the high frequency receiver, which made it difficult to follow patterns in the dynamic spectra from one band to the other. Moreover, only a few months of decameter Voyager data could be used, whereas it was possible to use many months of hectometric data, allowing better statistics. It was therefore chosen to compare 6 months of simultaneous observations performed on Voyager in the hectometric range, and at Nançay in the decameter range. It was shown that the same fluctuations were observed for the non-Io decameter emission and at hectometer wavelengths, thus giving the first indication that these are probably the same emission (Genova et al., 1987). This means that the lowest limit of the Jovian decameter radio emission, at least the non-Io one, is as low as ~ 100 kHz (Alexander et al., 1981, showed that the Io control is still felt at least down to 2 MHz, but the lower frequency limit of the Io influence is not exactly known). Thus the source of emission extends from close to the surface up to ~ 4 Jovian radii — to compare with the highest altitude for Saturn kilometric radiation, ~ 5 Saturn radii.

5. Conclusion

Spacecraft observations of the planetary radio emissions are certainly extremely important: they made it possible to observe the emissions from the Earth, Saturn and Uranus, in the kilometric range, and the low frequency part of the Jovian decametric radiation. Moreover, they are free from Earth-produced periodicities. They also give access to directions of observation invisible from the Earth, at high Jovigraphic latitude or away from the Sun direction, and sometimes allow *in situ* observations. But, although they are limited to the high frequency part of the Jovian radio emission, ground-based observations allow also one to study important problems for which space observations are not suitable, in particular concerning the fine structure of the emission, for which high time and frequency resolution are needed. For example, one has now to understand better the origin of the modulation and high frequency lanes, of the N-bursts and splitting, and to study the fine structure of the arc pattern, the polarization of S-bursts, etc. Moreover, statistical studies of the characteristics of the emission observed from the ground over very long periods of time permitted to find the dominant phenomena which control the emission. Such studies are still needed to solve some crucial problems. The polarization of the emissions must be precisely measured, one must go on in the investigations of the exact location of the source(s) of the Io and non-Io emissions, and of the effect of the solar wind on the non-Io events, etc. For some of these problems (at least the two last ones) it would be preferable to have simultaneous observations from the ground and from space, but in the light of the recent advances on these subjects, it is likely that progress can be made from ground-based observations alone, which are the only available by these

days. Moreover, since the importance of understanding globally Jupiter's environment is now well recognized, the way is opened to the study of new problems, for instance the possible correlation of the radio emission with auroras, torus fluctuations, etc. All this means that long term synoptic observations of Jupiter must go on, but also that the same kind of observations are needed at other wavelengths, in cooperation, which will be done in the frame of the International Jupiter Watch. Finally, two space missions to Jupiter are planned in the relatively near future, after the shuttle problems have been solved. Galileo will remain in orbit around Jupiter for several years, allowing long duration close observations of the planet, at all local times. Ulysses will fly by Jupiter, reaching relatively high latitudes. This access to new directions of observations, and to long duration space observations, will certainly provide important new results on radio emissions. But the radio receivers of these two spacecraft are, and will probably remain, limited to frequencies well below the highest emission frequency: to 5.6 MHz in the case of Galileo, and to 1 MHz in the case of Ulysses. During these missions, the necessary coverage of the decametric range will have to be obtained from the ground.

