Astron. Astrophys. 175, 287–288 (1987)

ASTRONOMY AND ASTROPHYSICS

Localization of Io and non-Io sources of Jovian decameter emission

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Received June 13, accepted October 14, 1986

Summary. The observation of interplanetary scintillations (IPS) of the decameter radio emission from Jupiter provides information about the structure and position of the sources of emission. The paper presents the analysis of all the observations made at Nançay during the years 1978 and 1979. We confirm the preliminary results of Genova and Boischot (1981) on the frequency drift on the IPS patterns indicating that the emission is spatially distributed along field lines, and the localization of Io-controlled A and B sources on opposite sides of Jupiter. We furthermore show here that the non-Io sources A and B behave exactly like the Io-sources. It is concluded that the non-Io emissions come from sources along magnetic field lines seen at large distance from the central meridian, on the East for the non-Io-B source and on the West for the non-Io-A. The emission mechanism is thus to be the same for Io-controlled and Io-independent sources.

Key words: Jupiter – radio emission – interplanetary scintillation

1. Introduction

Information about the structure and the position of Jovian sources of decameter radio emission (DAM) can be obtained from the study of interplanetary scintillations (IPS), which produce intensity modulations with characteristic times of about 1 second (Douglas and Smith, 1967; Slee and Higgins, 1968; Genova and Leblanc, 1981). From indirect arguments, it has been assumed for a long time that the DAM sources are distributed in frequency along magnetic lines of force, and that the emission, at least for the sources controlled by Io, is at wide angle relative to the direction of the field line. In this case, the IPS spectral pattern must drift in frequency in a direction which depends on the solar elongation and whether the source is on the Eastern or Western side of the planetary disc (Genova and Boischot, 1981). Preliminary results have shown that this IPS drift can easily be seen on analog records of the dynamic spectra observed at Nançay (Boischot et al., 1980). Genova and Boischot (1981) documented earlier four examples of IPS in Io-A and Io-B sources, for different solar elongations. From the direction of the drift of the IPS, they concluded that the sources were both spread in space with frequency, and located on the Western and Eastern sides of Jupiter respectively, in agreement with the above assumption.

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Very Long Baseline Interferometry (VLBI) observations revealed that the source of emission at a given frequency is very small, with an angular diameter $<0''.1$, or a linear dimension <400 km, if there is no spatial coherence inside the source (Dulk, 1970; Lynch et al., 1976). Although these observations have been made only on Io-controlled sources, the many similarities between Io and non-Io sources suggest that the source model derived for Io-sources may well be valid for the non-Io ones. However, no direct proof of this has been given so far. The comparison of the IPS behaviour on Io and non-Io sources is then very important to study.

2. Observations

In the present work, we use the broadband (15–40 MHz) dynamic spectra obtained at Nançay on film (Boischot et al., 1980), and we apply the method described in Genova and Boischot (1981) to all the emissions observed during the years 1978 and 1979. A catalogue of these emissions has been published (Leblanc et al., 1981), with 412 emissions observed during the two years, but not all of them are suitable to study IPS. The drifting pattern can be clearly seen only on the emissions which are broadbanded and last more than a few minutes. Moreover, IPS are absent when the solar elongation of Jupiter is close to 180°, i.e. when the projection of the solar wind velocity on a direction perpendicular to the line of sight cancels, or close to 0°, when the scattering by the solar corona increases the apparent source size (Genova and Leblanc, 1981).

In the Nançay observations for 1978 and 1979, we found 70 cases where the IPS drift is clearly apparent. These events are spread over the two years as shown in Fig. 1. The absence of IPS for solar elongations close to 0° and 180° is obvious. For each case, the beginning and ending times of the emission, and the sense of the drift – toward low or high frequencies – have been noted from careful visual observations of the records, without knowing a priori the position of Jupiter. Then the emission tracks have been plotted in the usual way on a Io-CML (Central Meridian Longitude) diagram with different line styles for positively and negatively drifting IPS. The emissions corresponding to a position of Jupiter at the East, and at the West of the Sun, i.e. for opposite directions of the apparent solar wind velocity, have been plotted separately in Figs. 2a and 2b. From these figures, we can conclude that:

– for a given solar wind direction, the frequency drifts of A and B sources are, without exception, in opposite senses, in agree-

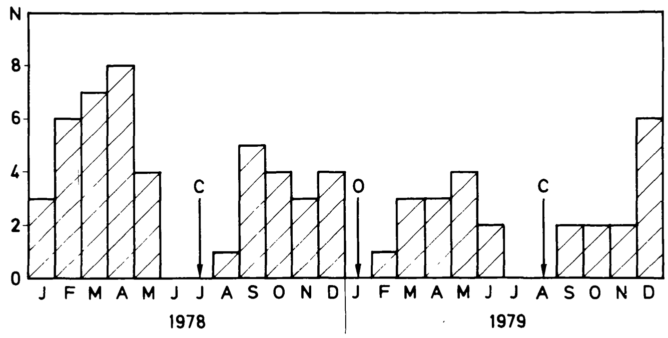

Fig. 1. Distribution of the 70 Jovian emissions for which the sign of IPS frequency drift has been determined. IPS are not observed near conjunction (C) and opposition (O)

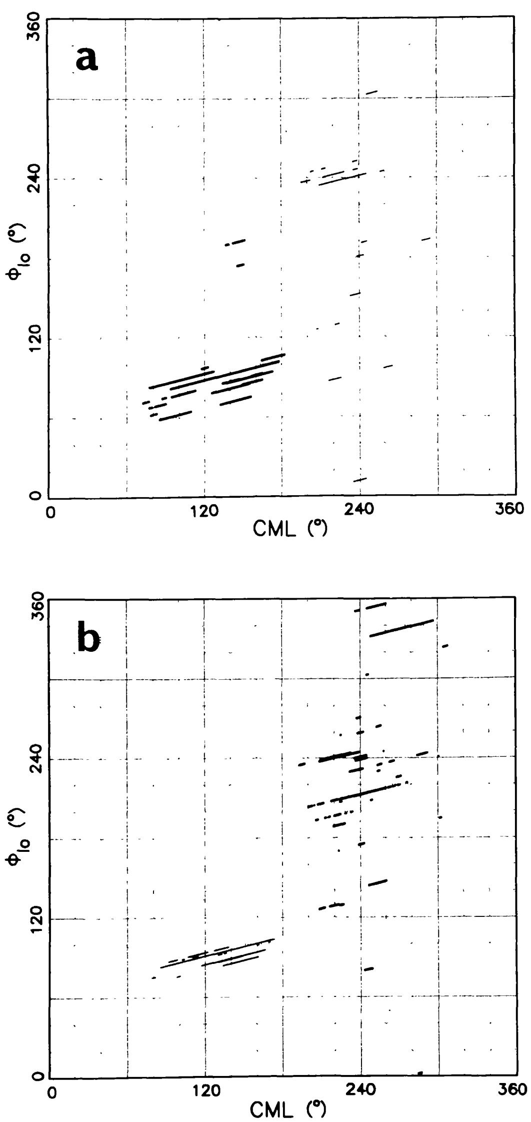

Fig. 2a and b. Io-CML diagram for the emissions observed in 1978 and 1979; **a** when Jupiter is at eastern solar elongations, and **b** when Jupiter is at western solar elongations. Thick lines correspond to IPS patterns drifting towards high frequencies, and thin lines to IPS patterns drifting towards low frequencies. Note the inversion of the drift sense between sources A and B in 2**a** and 2**b**

ment with the preliminary result of Genova and Boischot (1981).

– the drift sense always reverses at opposition and conjunction, i.e. when the apparent direction of the solar wind in front of the source reverses.

– *several emissions where IPS are observed correspond to non-Io sources, either A or B. These sources behave exactly like the Io-A and Io-B sources, with the same drift sense.*

An IPS scintillation index is difficult to determine quantitatively for varying sources such as those of Jupiter decameter radio emission, especially in the presence of strong ionospheric scintillations. But from visual inspection of the records it appears that no noticeable difference exists between the scintillation indices of Io and non-Io sources. The apparent sizes of the sources are thus likely to be similar.

3. Conclusion

The main conclusion of this study is that Io and non-Io sources have the same structure and the same position, i.e. at large distance from the central meridian. Because the high frequency limit of Io and non-Io emissions are essentially the same (Barrow and Alexander, 1980) and due to the fact that they are polarized in the same sense, we can also conclude that they all come from the northern hemisphere. Thus, Io and non-Io emissions are radiated, at each frequency, by very small sources in a very thin hollow conical sheet at large angle to the magnetic field lines. These sources are spread spatially with frequency. As there is no privileged line of force involved in the non-Io emission, it seems reasonable to infer that electrons do precipitate all the time at every longitude, very likely near the L shells corresponding to the orbit of Io. The effect of Io is then only to enhance the emission from an extended region around the Io flux tube. The extension of these regions, about 90° in longitude, can be derived from the "width" in longitude of the sources in the Io-CML diagram.

Two important characteristics of the non-Io sources still remain to be explained: (i) the dependence of the occurrence and intensity of the emission on CML, which is, as a first approximation, similar to that of the Io-sources, and could be due to a propagation effect close to the source or in the Io plasma torus, and (ii) the inversion of the relative intensity of A and B sources when seen from the day side or the night side of the planet, which was observed by the Voyager spacecraft only for the non-Io sources (Alexander et al., 1981).

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