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INFLUENCE OF THE SATELLITE Io ON JUPITER'S DECAMETRIC RADIO EMISSION

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ABSTRACT

An analysis of the influence of the satellite Io on Jupiter's decametric radio emission was carried out utilizing observations recorded at Kodaikanal and Boulder. The influence is found to be complicated and is different at the three sources. It is suggested that the Io related emission can be due to Cerenkov radiation by fast electrons acting as a well-separated stream.

INTRODUCTION

SINCE the discovery of radio emission from Jupiter by Burke and Franklin (1955), considerable experimental and theoretical work has been carried out on its decametric radio emission. The radio period of Jupiter was determined with considerable accuracy and a co-ordinate system known as system III has come into use. Bigg (1964) found that the phase of the Jovian satellite, Io, has a strong influence on the frequency of occurrence of its decametric radio emission, the probability of occurrence being high when the phase of Io (from superior geocentric conjunction) is around 90° and 250°. Extending the above work Duncan (1965) found that the occurrence probability is high when the Jovian longitude of Io is around 200°. It is significant that the plane containing Jupiter's magnetic axis is also at the same longitude.

OBSERVATIONS

In the present analysis, Jovian events recorded at Kodaikanal (latitude $10^\circ \cdot 2$ N, longitude $77^\circ \cdot 5$ E) during 1963–65 at $22 \cdot 2$ Mc/s were used. The equipment consists of a simple receiver operated as a phase-switching interferometer with a base line of 43 λ. The operation of the instrument was restricted to interference-free periods at nights, when Jupiter came into the antenna beam. About 100 storms were recorded during this period. The number of storms recorded is small because of the low sensitivity of the equipment and restricted observing periods. To supplement the above data and to confirm the results obtained, Jupiter data recorded at Boulder during 1964 (Warwick and Dulk, 1965) were also used. The occurrence frequencies of bursts at different longitudes of Jupiter using Kodaikanal and Boulder data are shown in the histograms of Fig. 1. Two major sources around 160° and 250° are seen along with a minor source at 320°. The longitude limits of the three sources are: Source I at 120–180°; Source II at 220–280° and Source III at 300–340°. The variation of the frequency of occurrence with phase of Io is shown in the histograms of Fig. 2 using Kodaikanal and Boulder data separately. In spite of the scatter present, the influence of Io is seen with peaks at phases of Io, 90° and 240° (The phase was reckoned as the angular distance travelled by Io from the nearest superior geocentric conjunction).

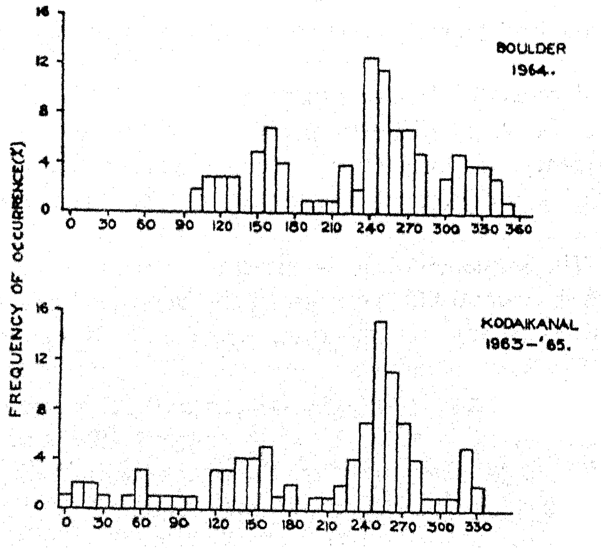

FIG. 1. Frequencies of occurrence of bursts at different longitudes of Jupiter.

Duncan (1965), while confirming the influence of Io discovered by Bigg, concluded that the probability of burst occurrence is high at Jovian longitudes of 110° and 250°. The present observations confirm the existence of the two maxima at Io phases of 90° and 240°, but it may be seen that the early source is at a longitude of 160° instead of 110° as indicated by Duncan. Both the Kodaikanal data for 1963–65 and the Boulder data or 1964 were combined and used to investigate in detail the influence of

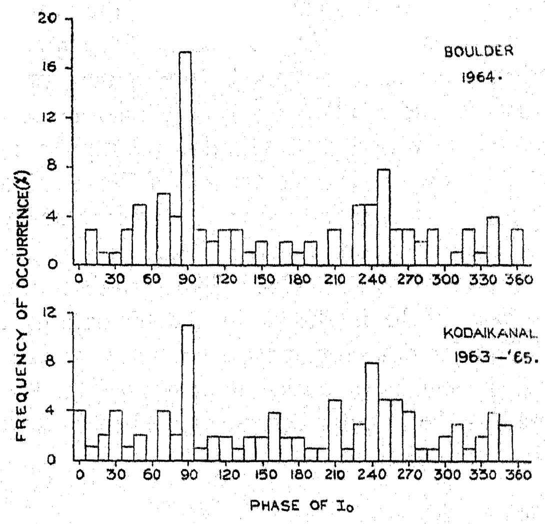

Fig. 2. Histograms showing variation of the frequency of burst occurrence with phase of Io.

Io on individual sources. The histograms of Fig. 3 show the frequencies of occurrence of bursts at different phases of Io for the three sources. In Fig. 4 the frequency of occurrence is shown against the Jovian longitude beneath Io at the time of burst. The results can be summarised as follows:

Source I.—The influence of Io is maximum for emission at this source. The phase of Io, is around 90° for most of the bursts. The Jovian longitude beneath Io corresponding to maximum frequency of occurrence. is not uniquely defined. Two maxima are seen at 200° and 240°. One possible interpretation of this result is that the influence of Io is maximum at phase of 90° and when it is at or near the main source. The magnetic axis at a Jovian longitude of 200° does influence the emission but only in an indirect way, by its proximity to one side of the main source.

Source II.—The probability of radio emission from this source, independent of Io, is quite high and as such the influence of Io is not very clearly seen. The Jovian longitude beneath Io shows wide scatter with a maximum around 180°.

Source III.—The probability of burst occurrence from this source is generally quite low. The influence of Io on emission from this source is, however, quite marked, the corresponding phase being 240°. There is, however, a less marked second maximum corresponding to Io phase of 50°. The Jovian longitude beneath Io shows a peak at 280°.

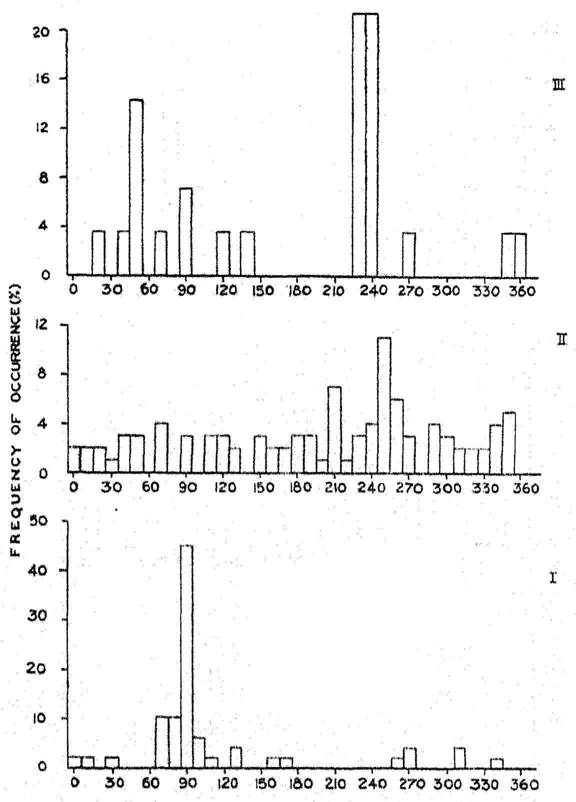

FIG. 3. Variation of frequency of burst occurrence with phase of Io for the three sources (Source I—bottom; Source II—middle; Source—III—top).

DISCUSSION

Duncan (1965) found, from an analysis of bursts at a frequency $\geqslant 30$ Mc/s that the presence of Io above the plane containing the magnetic axis of Jupiter increases the probability of occurrence of radio emission. Also such an emission is expected to be confined to the Jovian longitudes of 110° and 250°. In the present analysis the early source, the radiation from which shows a remarkable correlation with the phase of Io, is present at 160° Jovian longitude. It is significant that bursts from the early source are almost always associated with the phase of Io around 90°. About 50% of the bursts emitted by the late source are associated with the phase of Io around 240°. In contrast, the main source has a less prominent maximum corresponding to the Io phase of 250°, accounting for less than 25% of the bursts. The influence of Io can thus be seen to be complicated and radio emissions from the early and late sources are mainly Io related. It is quite

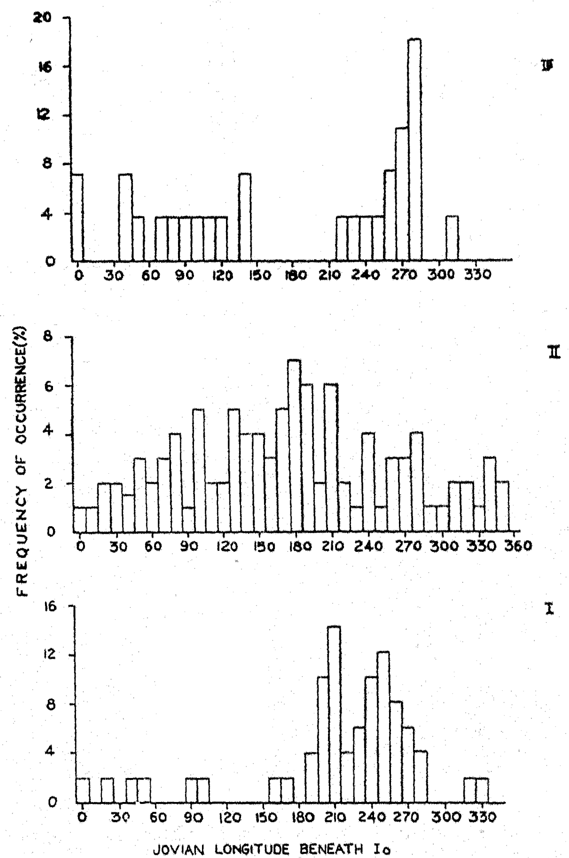

FIG. 4. Variation of frequency of occurrence with Jovian longitude beneath Io at time of burst. (Source I—bottom; Source II—middle; Source III—top).

probable that the radio emission associated with Io, have different physical characteristics from the general emission, caused by slightly different mechanism. Riihimaa (1966) reported from observations near 19 Mc/s that the bursts originating at the early and late sources show fine structure which is observed only on rare occasions at the main source. In view of the association between the fine structure of the bursts and Io, we may consider that the mechanism of emission causing the fine structure is different from that causing the general emission. Duncan (1965) suggested, as a possible explanation, the dumping of electrons on to Jupiter, due to the disturbance of the magnetic field caused by the presence of Io above the plane containing the magnetic axis of Jupiter. Though this explanation is convincing, it cannot completely explain the present results for the early source, that the probability of occurrence is high not only when the Jovian longitude beneath Io is about 200° but also 240°. It seems more likely that by some mechanism, Io increases the probability of burst occurrence by its presence at or near the main source. We may now refer to an observation by Douglas and Smith (1963) who, while discussing various possibilities of radiation configurations, mentioned the possibility of only one true source, corresponding to the longitude of the main source, existing with radiation cones as shown in Fig. 5. With such a configuration it is possible to see radiation as originating at three points on Jupiter corresponding to the true source at central meridian and at the limbs of Jupiter. On the basis of this configuration, it is possible to expect the radiation propagated tangential to the planet to have characteristics different to that propagated perpendicular to the planet. Propagation of radio emission almost at right angles to the direction of motion of the electrons is possible for single electrons passing through a plasma. The angular spectrum of emission for such a case is given by Cohen (1961). We may assume that the dumping of electrons aused by the presence of Io is in a stream of single electrons or rather a ream of electrons sufficiently well separated to act independently. In this case the emission is almost perpendicular to the stream and due to the incoherence, fine structure or bursts with pulses of narrow band-width (Riihimaa, 1966) may be generated. The above explanation is consistent

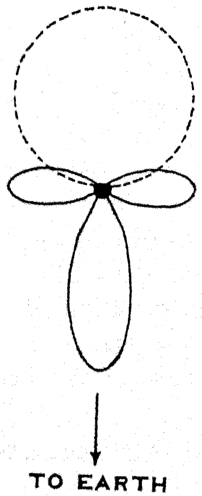

FIG. 5. Possible radiation cone configuration responsible for the three sources observed (after Douglas and Smith, 1963). Source II cone is centred on the earth. The dotted circle represents Jupiter and the heavy point, emission region.

with the observed lack of fine structure for the emission from the main source. The case of the late source appears to be more complicated. The emission from this source shows a remarkable correlation with the phase of Io, the mechanism of emission, however, appears to be more complicated as the Jovian .longitude beneath Io turns out to be 280°, which is almost perpendicular to the plane containing the magnetic axis of Jupiter. The probability of burst occurrence is quite low for the third source and the influence of Io on this source, though marked, is not as much as on the source I. It seems likely that the capability of Io's influence to generate radio emission is controlled in a complicated way not only by its position with respect to the main source but also by its position with respect to the magnetic axis of Jupiter. A more exhaustive study is needed to clarify the position.

CONCLUSIONS

The present analysis confirmed the results obtained by earlier workers as to the influence of the satellite Io on the Jovian decametric emission. The influence of Io is complicated and is different at different sources. There is support for the idea that there is only one true source of radio emission on Jupiter which becomes visible as three sources viewed from the earth corresponding to the two limb positions and the central meridian position of the source. The Io-related emission is probably caused by fast electrons dumping on to Jupiter as a well separated stream causing incoherent radiation at almost 90° to the direction of the stream. Such a mechanism may also be responsible for the fine structure of observed emission from the early and late sources because of the incoherence of the radio emission.

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