in color to the aggregates and presumably consisting of organic material. The lack of chemical interaction between fine carbonate particles suspended in surface seawater appears to be the result of protection of the grains from the water by resistant organic coatings.

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4. Contribution 65-3 from the Marine Science Center, Lehigh University. Contribution 368 from the Bermuda Biological Station. This work was supported by ONR contract Nonr 610(07).

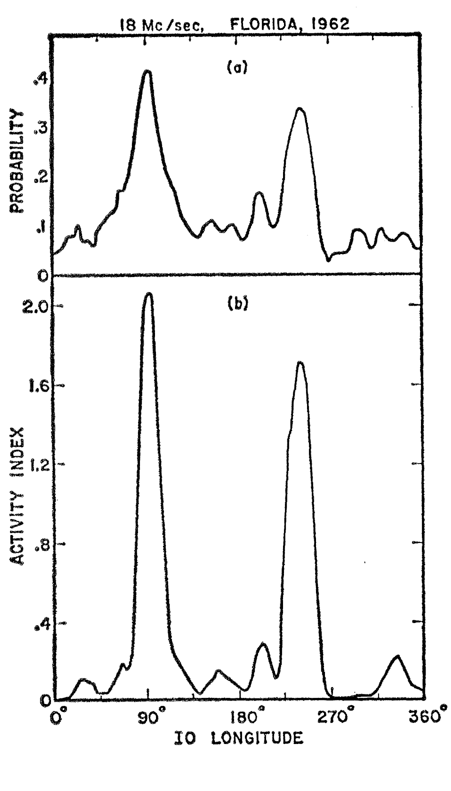
8 April 1965

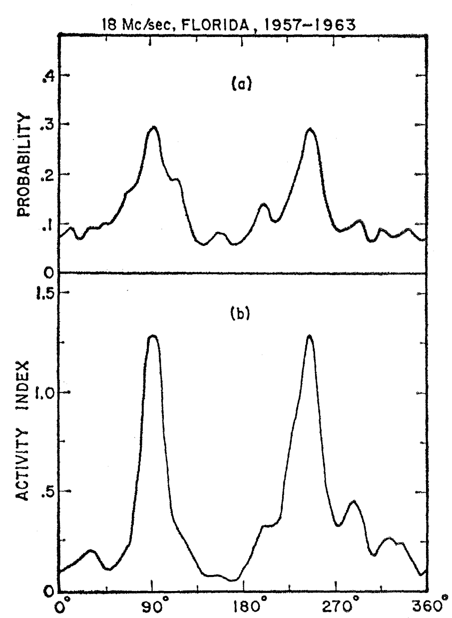
Jupiter's Decametric Emission Correlated with the Longitudes of the First Three Galilean Satellites

Abstract. *An analysis of data obtained at a variety of frequencies since 1957 has confirmed Bigg's observation that the satellite Io appears to control the emission of decametric radio energy by Jupiter. The correlation is stronger when intensity, rather than simple probability, is included in the analysis. There is also evidence of a similar influence by the satellites Europa and Ganymede.*

In 1964, Bigg (*1*) found a striking dependence of Jupiter's decametric radio emission on the angular position of Io, the innermost Galilean satellite. The radio data were those obtained during 1961, 1962, and 1963 by J. W. Warwick of the High Altitude Observatory at Boulder, Colorado. At the same time, Bigg reported that he had as yet found no definite correlation between the decametric radiation and the positions of the remaining three Galilean satellites.

The University of Florida Radio Observatory has extensive multifrequency records of Jovian radio emission going back to 1957. These data are stored in punch-card form, so that a search for the satellite effect could be made merely by preparing a suitable computer program. As Fig. 1 indicates, the results of this search have amply verified Bigg's initial finding with respect to the influence of Io. Fig. 1*a* shows how the probability of receiving radiation at a frequency of 18 Mc/sec varied with the longitude of Io during the 1962 apparition of Jupiter. As usual, the longitude has been taken as zero when the satellite was at superior geocentric conjunction. The conspicuous probability peaks near 90° (western elongation) and 240° are in essential agreement with Bigg's work.





Figs. 1 and 2. Influence of Io on 18 Mc/sec radiation from Jupiter during the apparition of 1962 (Fig. 1, left) and during the apparitions of 1957–1963 (Fig. 2, right).

Figure 1*b* shows the same data, but here the ordinate is the Jovian "activity index" (*2*). In computing this index, the probability of occurrence is weighted through multiplication by the flux density of the received emission; thus the activity index reflects both the probability of receiving radiation and the intensity of that radiation. The fact that the peaks in Fig. 1*b* are far more pronounced than those in Fig. 1*a* suggests that Io imposes an intensity modulation on the emission, as well as controlling its occurrence.

Figure 2 is identical with Fig. 1, except that a computer program has been used to combine all of the 18 Mc/sec observations made during the seven apparitions from 1957 through 1963. The similarity of the two figures indicates that the Io influence is relatively stable in time. If, for example, gross changes occurred in the locations of the peaks, the peaks themselves would be broadened and degraded when data covering long periods of time are merged.

In the initial analysis emphasis was placed on the observations made at 18 Mc/sec. Since this frequency represents a kind of optimum compromise between the characteristics of the Jovian emission and the limitations imposed by the terrestrial ionosphere, the 18 Mc/sec data are generally the most abundant and the most reliable. The study has nevertheless been extended to a number of other frequencies, and the results for the 1962 apparition are shown in Fig. 3. The forms and locations of the two major peaks appear to be stable over this range of frequencies, although the relative amplitude of the peak at 240° decreases steadily as the frequency increases. On the other hand, data recorded at the lower frequencies (for example, 5 and 10 Mc/sec) at a field station in the southern hemisphere do not seem to conform to the pattern of Figs. 1 and 2. This is perhaps not surprising, since the apparent structure of the Jovian decametric sources themselves undergoes a radical change at frequencies below 15 Mc/sec (*3*).

It is well known that between 15 and 40 Mc/sec there are three major regions of activity on the planet, one of which often appears to be bifurcated (*4*). In a suitably defined longitude system (known as System III or λ_{III}) these

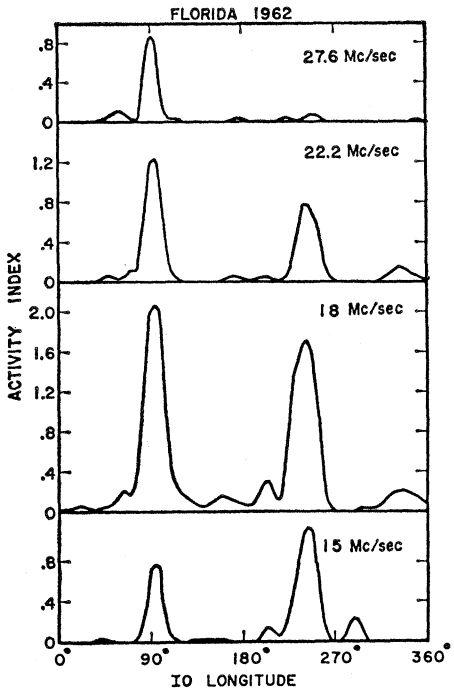


Fig. 3. Influence of Io on Jovian radiation of various frequencies during the apparition of 1962.

"sources" maintain fixed positions, although around 1960 their apparent rotation period changed from $9^{h}55^{m}29^{s}.35$ to $9^{h}55^{m}30^{s}.52$ (at 18 Mc/sec) (*3*). Bigg investigated the influence of the angular relationship between Io and the decametric sources through a contour plot such as is shown in Fig. 4. This figure is based on all of the data for 18 Mc/sec obtained during 1957–1963 at the University of Florida; the computations took account of the change in rotational period since 1960, and resulted in an appreciable sharpening of the

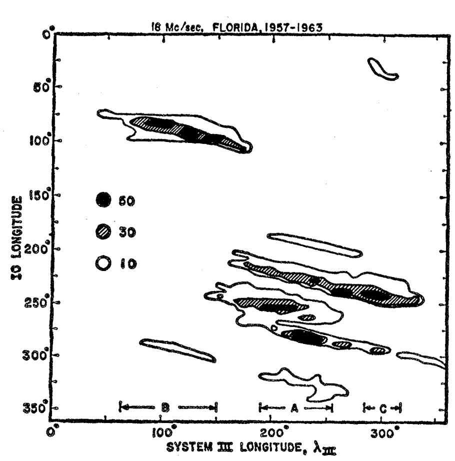


Fig. 4. Jovian decametric activity as a function of both Io longitude and system III longitude (λ_{III}). The contours represent the activity index for 18 Mc/sec emission during the apparitions of 1957–1963.

contours as compared with an earlier analysis in which this refinement was omitted.

In agreement with Bigg's work, it appears that the most active source, *A* (at $\lambda_{III} \cong 250°$), can be stimulated over a relatively wide range of Io longitudes. On the other hand, the secondary source, *B* (at $\lambda_{III} \cong 140°$), is observed only over a narrow span of Io longitudes. The tertiary source, *C* (at $\lambda_{III} \cong 320°$), is similarly more sensitive than *A* to the position of Io. It seems quite likely that the greater probability of receiving emission from *A* is related to the tolerance of that source for changes in the location of the satellite. The general slope of the contours in Fig. 4 is simply a time effect; that is, if one regards the horizontal axis as a time axis, making a giant clock of Jupiter, the slope of the contours indicates the rate at which Io longitude increases in this time system.

If the influence of Io is tidal in nature, one might anticipate similar, but smaller, effects from the other major satellites. The tide-raising forces of the second and third satellites, Europa and Ganymede, are respectively about 1/7 and 1/9 that of Io. Figure 5 shows a polar plot of activity index versus satellite longitude for Io, Europa, and Ganymede, the data for 18 Mc/sec from the apparition of 1962 again being used. There appear to be reasonably pronounced activity peaks for Europa and Ganymede longitudes between 270° and 360°, and for Ganymede between 80° and 180°. When the longitudes of Europa and Ganymede are either equal or differ by 180°, the joint tide-raising force is ¼ that of Io. Long ago, Laplace (*5*) showed that the mutual perturbations of the three satellites bring them exactly into line at intervals of about 7 days, with Io and Ganymede on one side of the planet and Europa on the other. Because of the near-harmonic relationship between the periods of the three satellites, an approximate realignment occurs 3½ days after syzygy, with Europa and Ganymede on the same side of Jupiter and Io on the opposite side. The line of syzygy precesses about Jupiter in the retrograde sense with a period of 437 days, and it is interesting to note that during the most productive portion of the 1962 apparition the longitude of the line changed from 180° to 80° (or from 360° to 280°), covering just that portion of the polar diagram in which the activity of Europa and Ganymede appears to peak. A study similar to that

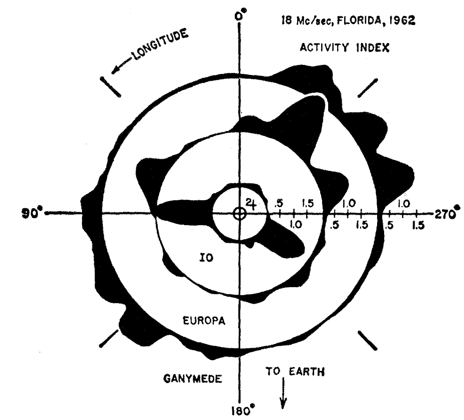


Fig. 5. Jovian 18 Mc/sec activity indices versus the longitudes of Io, Europa, and Ganymede during the apparition of 1962.

shown in Fig. 5 and based on the data for 18 Mc/sec from 1957 through 1963 failed to show localized peaks for the second and third satellites, perhaps because of the "smearing" caused by precession of the line of syzygy during the 7-year period.

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6. Supported by the NSF, the Army Research Office (Durham), and the ONR.

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Microseisms from Hurricane "Hilda"

Abstract. *As hurricane "Hilda" crossed the Gulf of Mexico the dominant period of the microseisms shifted from about 8 to 5 seconds as the eye reached water about 150 to 200 meters deep. The conversion of wind energy to microseismic energy is most efficient in water depths from 20 to 200 meters. There is no evidence that two periods, one twice the other, are present.*

The vicinity of the Gulf of Mexico is particularly well suited for the study of microseisms: the Gulf is a restricted body of water through which accurately mapped hurricanes move fairly frequently. The recent hurricane