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POLARIZATION AND ANGULAR EXTENT OF THE 960-Mc/sec RADIATION FROM JUPITER*

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Following the discovery by Sloanaker[1] of unexpectedly intense 10-cm radiation from Jupiter, Bolton initiated studies of the planet at a wavelength of 31 cm (960 Mc/sec) at the above observatory.[2] These and other investigations[3] have led to the suggestion that the radiation originates in a "Van Allen belt" surrounding Jupiter.[3] If the emission has its origin in such a belt of electrons spiralling in a trapping magnetic field, the angular extent of the source of the radiation is likely to be several times the diameter of the planet. In addition, some degree of polarization of the radiation would be expected.

Observations to test these predictions are being made with a variable-spacing interferometer, and some results are reported here. The source is found to be strongly linearly polarized, the radiation with the electric vector parallel to the equatorial plane of the planet being approximately 1.7 times as intense as in the orthogonal polarization. The radiation comes from a region several times the diameter of the disk and is more strongly polarized in the outer parts.

The observations were made possible by the advanced instrument available at this observatory, namely a phase-switched interferometer comprising two 90-foot antennas which can be moved on railroad tracks between stations with separations of 200, 400, 800, and 1600 feet. The corresponding fringe spacings at 960 Mc/sec are approximately 18, 9, 4.5, and 2 minutes of arc. (The diameter of Jupiter at the time of the observations was ~0.6 minute of arc.) The instrument can be used to completely determine the polarization of a radio source by observing with different orientations of the horn feeds on the two antennas.[4] Each horn can be rotated on its own axis; one is motorized and can be set alternately parallel and perpendicular to the other during an observation. Observations of nonpolarized radio sources have shown that the signal received in the cross-polarized condition is approximately one percent of that received in the parallel condition.

The polarization of the planetary emission was demonstrated conclusively by the large interference pattern recorded when one horn was set to receive radiation with the electric vector in position angle -45° and the other to receive the orthogonal polarization. The phase of this interference pattern indicated that the polarization was linear, with the electric vector approximately in position angle 90° (E-W), i.e., in the planet's equatorial plane. No detectable pattern was observed when the antennas were cross polarized in position angles 0° and 90°. This implies the absence of any circularly polarized component ($\leq 6\%$), and that the direction of the electric vector of the linear component is within $\pm 12°$ of position angle 90°.

If the electric vector is assumed to lie directly E-W, the degree of polarization[5] is given by the ratio of the interference pattern recorded when the horns are cross polarized in position angles 45° and -45°, to that recorded when the horns are identically polarized at one of these position angles. Observations of this type, at an antenna separation of 400 ft made on April 2, 3, 11, and 12, 1960, gave values for the degree of polarization between 25 and 43%, with a mean value of 33%.

The polarization was also determined by comparing the intensity received with both horns parallel and oriented E-W and N-S on successive days (April 12, 13). These observations are in qualitative agreement, but given a lower degree of polarization (mean 22%). The significance of this difference is not yet clear.

From April 17 to April 21, observations were made with an antenna separation of 800 feet by one of the authors and David Morris. By observing the source at various hour angles, a range of effective baselines (and hence fringe separations) was obtained. The apparent intensity of all components of the radiation decreased with decreasing fringe size (Table I), indicating that the source was being resolved. However, the polarized component decreased more rapidly, and therefore the outer regions of the source are more strongly polarized. The present observations are insufficient to determine a detailed distribution of intensity, but are consistent with an equatorial ring of mean diameter about 2 minutes of arc, i.e., about three times the diameter of Jupiter.

Of the theories proposed to account for the Jovian decimeter radiation,[2,6] only the cyclotron and synchrotron theories predict strong linear polarization.

For the cyclotron theory the observed intensity of radiation can be accounted for on the basis of electron densities similar to those in the earth's outer Van Allen belt and a field ~ 300 gauss in the emitting region. This would imply a field $\sim 10^4$ gauss at the surface of the planet. It seems likely that such a field could be detected by optical means.

The synchrotron theory would not need such strong fields, but would demand a vastly greater density of relativistic electrons.

Observations of the polarization and source size as a function of frequency appear to be a powerful method of discriminating between the cyclotron and synchrotron theories. For the cyclotron case Field[7] has predicted a rapid change of the polarization with frequency. No detailed theory is yet available for the synchrotron case, but elementary considerations suggest that the observed sense of polarization would be predicted and that there would not be a rapid change with frequency. The latter result follows from the consideration that unless there is a relationship between the energy of the electrons and their pitch angles at the equator, electrons of all energies will have similar orbits and mirror points.

These observations were made possible by the unique instrument which is due to J. G. Bolton, and by the highly sensitive receiving equipment designed by G. J. Stanley. We wish to thank Dr. G. B. Field for informing us of his results prior to publication, and Professor Leverett Davis for helpful discussions.

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[1]E. F. McClain and R. M. Sloanaker, Paris Symposium on Radio Astronomy, edited by R. N. Bracewell (Stanford University Press, Stanford, California, 1959), p. 61; C. H. Mayer, Astron. J. 64, 43 (1959).

[2]J. A. Roberts and G. J. Stanley, Publs. Astron. Soc. Pacific 71, 485 (1959).

[3]F. D. Drake and H. Hvatum, Astron. J. 64, 329 (1959).

[4]M. H. Cohen, Proc. Inst. Radio Engrs. 46, 172 (1958).

[5]Ratio of the intensity of the polarized component to the total intensity (2 planes of polarization).

[6]G. B. Field, J. Geophys. Research 64, 1169 (1959).

[7]G. B. Field, J. Geophys. Research (to be published).

Table I. Mean amplitude of interference fringes in arbitrary units.

Effective baseline (wavelengths) Fringe spacing (minutes of arc)		390 8.8	780 4.4	Extinguished part at 780λ
⇉ E-W component		40	23	17
↗↗ Position angle -45°		33	21	12
↑↑ N-S component		26	17	9
↖↗ Cross polarized 45°, -45°		10	≤5	≥5
↑→ Cross polarized 0°, 90°		≤4	≤4	
Percentage polarization	Method 1	30	≤24	≥42
	Method 2	21	15	31