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OBSERVATION OF SATURN AT 11.3 CENTIMETERS

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The recent report of the detection of linearly polarized emission from Saturn at 9.4 centimeters by Rose, Bologna, and Sloanaker[1] has emphasized the need for more detailed study of this planet at decimetric wavelengths. The presence of a polarized nonthermal component in the emission from Saturn would suggest a similarity with Jupiter, where study of the radio emission has provided extensive new information about that planet. However, the reported high percentage polarization of the nonthermal component (at least $51 \pm 22\%$), and the orientation of the polarized emission parallel to the polar axis of Saturn impose very special conditions in the theory which adequately explains the emission from Jupiter, namely synchrotron radiation from relativistic electrons spiraling in the magnetic field of the planet.[2]

In July and November 1963 the Parkes radio telescope, which has a beam width of 7.4′ at 11.3 cm, was used in conjunction with a parametric amplifier receiver[3] having a system noise temperature of 180°K to make a series of measurements of the emission from Saturn. Observations were made by setting the aerial beam ahead of the planet and allowing it to drift through the beam at the sidereal rate; each drift lasted four minutes. The receiver output, smoothed with a five-second time constant, was displayed on a pen recorder and was also recorded every two seconds on punched tape. A series of observations of Saturn normally consisted of four drift curves at each of four polarization-position angles separated by 45°, each series occupying about $1\frac{1}{2}$ hours. Noise-calibration signals were recorded after each set of four drift curves and several scans were made across the sources MSH 21-2$\underline{1}$ and 3C 444, which were used as reference sources. These sources were measured with two orthogonal polarizations to obtain their true intensities. Observations were taken on 22 and 23 July and on 12 and 14 November 1963, on which dates the numbers of usable drift curves were 47, 31, 21, and 36, respectively. On 23 July the observing procedure was altered, and drifts were taken only with the electric vector of the feed parallel and perpendicular to the polar axis of Saturn, that is, in position angles 6° and 96°, respectively.

Figure 1 shows a plot of the digitized recording of a single scan taken on 23 July and the average of a group of four scans containing this scan.

For each group of four scans the amplitude of the best fitting beam shape was estimated and normalized against the noise calibration. For each day the data for each position angle were averaged and converted into a fraction of the mean intensity for the four position angles. The results are shown in Fig. 2. As irregularities in some of the scans made it difficult to fit a unique baseline and beam shape to them, two independent analyses were carried out. The two results are shown by full lines (analysis A) and broken lines (analysis B). The observations of 23 July gave an intensity by both estimates which was

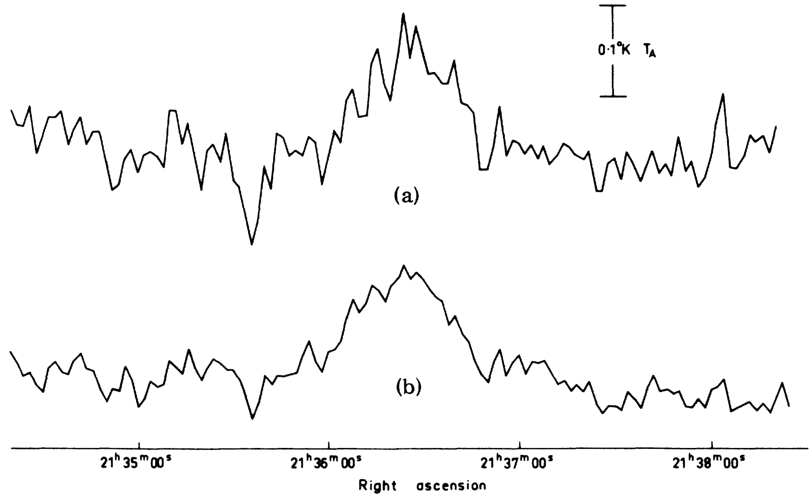

FIG. 1. 11.3-cm drift scans of Saturn taken on 22 and 23 July 1963 at declination −15° 32.0′. (a) A single scan at polarization-position angle 6°. (b) Average of a group of four scans containing (a).

6% higher at position angle 6° than at position angle 96°.

A least-squares fit of the data to the expression

$$I/I_0 = 1 + Q\cos 2p + U\sin 2p$$

was carried out, where I is intensity normalized to the mean intensity I_0 for the date, Q and U are normalized Stokes coefficients, and p is polarization-position angle. The data of 23 July gave a value of Q only, since they were taken with polarization angles close to 0° and 90°. When averaged with weighting factors based on the number of observations involved, the data for all four dates gave a mean degree of polarization of 3.3% in position angle 58° by analysis A and 0.6% in position angle 25° by analysis B. Making due allowances for the uncertainties of our data we estimate an upper limit of approximately 6% for the degree of polarization of Saturn's 11-cm emission averaged over the period of our observations. On the other hand, Rose, Bologna, and Sloanaker observed the planet in two polarizations only and concluded that its intensity was 51% greater when observed with their aerial polarized in a north-south direction than with it polarized in an east-west direction. These observations were made with an 84-foot telescope at 9.4 cm. Since the position angle of Saturn's polar axis was approximately 6° during 1962-1963, they took this to indicate a degree of linear polarization of 22 ± 8% in the general direction of the polar axis. In terms of the nonthermal component, which was estimated to account for 43% of the 9.4-cm emission, the degree of polarization was calculated to be 51 ± 22%.

In view of the small difference between the

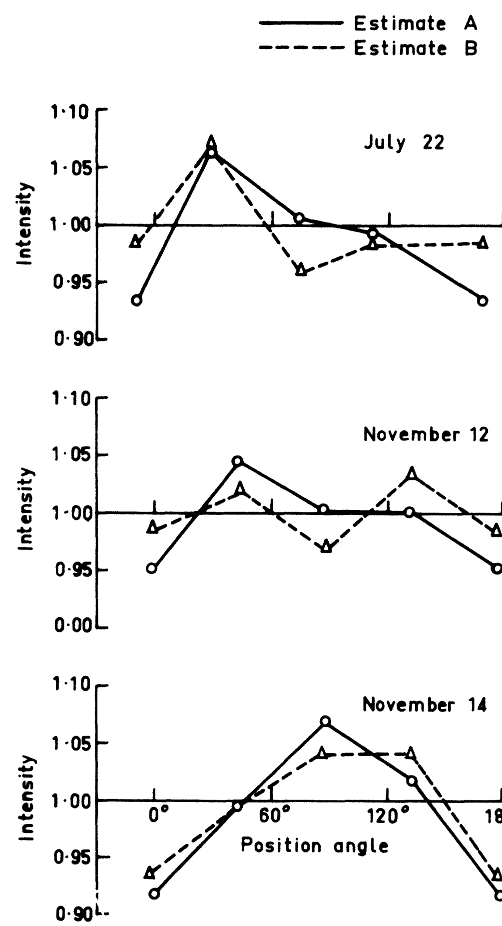

FIG. 2. Normalized intensity plots as a function of polarization-position angle for three dates in 1963.

9.4-cm wavelength used in the above observations and the 11.3-cm wavelength used by us, we find it difficult to explain the large discrepancy between the values arrived at for the degree of polarization. However, we would point out that the observations with the 210-foot telescope enjoyed a more favorable signal-to-noise ratio than those made with the 84-foot telescope and would be less troubled by confusion effects with the general background of weak radio sources.

Rose, Bologna, and Sloanaker have discussed a model for the nonthermal generation process in which Saturn's magnetic axis is steeply inclined to the rotation axis. The synchrotron emission from particles radiating in this field would then show pronounced variations of polarization and intensity with rotational phase of the planet. It is possible, though unlikely, that the discrepancy referred to above can be explained by a different observing sequence in relation to the rotation period of the planet. In our case the observing sequence was not specifically planned to bring out effects of this nature. However, an analysis of our data, assuming a $10^h 20^m$ rotation period and polarization varying with a period of $5^h 10^m$, showed that the polarization at no phase reached 10%.

The effective brightness temperature of Saturn can be calculated from known optical dimensions and the measured flux density. The flux density of Saturn was related to that of 3C 444 which was estimated to be 4.68×10^{-26} W m^{-2} (cps)$^{-1}$. The latter value was derived from a comparison of intermediate intensity sources observed at Parkes with the accurately calibrated flux densities given by Conway, Kellerman, and Long.[4] The flux density of 21-21 was 1.32 times that of 3C 444. The mean intensity of Saturn on 22 and 23 July was 0.0497 of 3C 444 and that found for 12 and 14 November was 0.0405 when the area of the disk of Saturn was 0.822 of the July value. The error (standard deviation) in the July estimate, arising from the scatter of observational points, was 2.3% and for November was 4.2%. Both estimates of intensity are subject to the same systematic errors in assigning a flux to 3C 444, the greatest of which is the 10% error estimated by Conway, Kellerman, and Long for the absolute scale of 10-cm flux densities. The brightness temperatures calculated for July and November are 183 ± 4°K and 181 ± 7°K, respectively, giving a mean value of 182° with a 10% uncertainty due to possible calibration errors meantioned above. Here we have excluded any contribution from Saturn's rings.

This value may be compared with the value of 177°K deduced by Rose, Bologna, and Sloanaker, the value of 196°K measured by Drake[5] at 10.0 cm, and the 3.45-cm value of 106°K measured by Cook, Cross, Blair, and Arnold.[6]

The infrared temperature of Saturn is 123°K.[7] This would make the nonthermal contribution from the planet 59° at 11.3 cm. Observations at longer wavelengths would be of interest to determine the spectrum of the nonthermal component. An attempt was made to determine the intensity of the planet at 1410 Mc/sec on one occasion in 1963, but it was found that the planet was situated among background irregularities of comparable intensity. This made it difficult to determine its intensity accurately. With the 210-foot reflector the expected intensity of the planet at 1410 Mc/sec is of the order of the background irregularities expected over most of the sky so it is clear that a number of observations of the planet on different dates will be necessary to enable its intensity to be determined with good accuracy.

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