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PLANETARY RADIO ASTRONOMY OBSERVATIONS FROM VOYAGER 2 NEAR SATURN

J. W. Warwick, D. R. Evans, J. H. Romig,
J. K. Alexander, M. D. Desch, M. L. Kaiser,
M. Aubier, Y. Leblanc, A. Lecacheux, and
B. M. Pedersen

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Goddard Space Flight Center
Greenbelt, Maryland 20771

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ABSTRACT

Voyager-2 Planetary Radio Astronomy measurements obtained near Saturn have added further evidence that Saturnian kilometric radiation (SKR) is emitted by a strong, dayside source at auroral latitudes in the northern hemisphere and by a weaker (by more than an order of magnitude) source at complementary latitudes in the southern hemisphere. These emissions are variable both due to Saturn's rotation and, on longer time scales, probably due to influences of the solar wind and the satellite Dione. The Saturn electrostatic discharge bursts (SED) first discovered by Voyager-1 and attributed to emissions from the B-ring were again observed with the same broadband spectral properties and a $10^h11^m \pm 5^m$ episodic recurrence period but with an occurrence frequency of only about 30% of that detected with Voyager-1. During the crossing of the ring plane at a distance of 2.88 R_S, an intense noise event extending up to above 1 MHz was observed for about 150 sec. This event is interpreted to be a consequence of the impact/vaporization/ionization of charged micron-size G-ring particles distributed over a total vertical thickness of about 1500 km.

The Voyager-2 (V2) Planetary Radio Astronomy (PRA) instrument (1) made observations of several different radio-wave phenomena during the period immediately surrounding the August 26, 1981 Saturn encounter. We describe here three of those phenomena — Saturnian kilometric radiation (SKR), Saturnian electrostatic discharges (SED), and a remarkable noise event that was observed at the time of ring plane crossing. The Voyager-1 (V1) PRA instrument had discovered SED during the November 1980 Saturn encounter (2,3), and SKR has been observed by both Voyagers since January 1980 (2,4-7). We will discuss the SKR and SED observations made by V2 in terms of the new information they add to our current level of understanding of these two phenomena. For the unique ring plane event, we will simply describe our observations and will only briefly mention our current interpretation.

SATURNIAN KILOMETRIC RADIATION

Intense SKR dominated the radio spectrum at frequencies below 1 MHz as V2 approached the planet. After the time of closest approach when the spacecraft had crossed the ring plane and moved into the southern hemisphere the properties of the SKR changed dramatically.

These changes are illustrated in Fig. 1 which shows dynamic spectra of SKR measured between 1.2 kHz and 1.3 MHz for five consecutive rotations of Saturn spanning the 53-hr period near closest approach. The left-hand panels (Fig. 1a) are gray-shaded to display received signal intensity as a function of frequency and time; the right-hand panels (Fig. 1b) display the predominant sense of circular polarization, with light gray shading denoting right-hand polarized (RH) emission and black denoting left-hand polarized (LH) emisssion. The plots are aligned with respect to sub-solar Saturn longitude in the SLS (5) convention.

Prior to closest approach (top two panels in Fig. 1), the SKR fills the frequency range between 60 and 900 kHz and occasionally extends to frequencies as low as 20 kHz and as high as 1100 kHz. Although the SKR exhibits large fluctuations in intensity as a function of time, some activity is always evident in the two pre-encounter spectrograms. We find that the SKR polarization is almost exclusively RH before closest approach, although LH-polarized narrow-band SKR appears near 40 kHz from about 180° to 360° SLS in the second panel. This same morphology, including the observation of narrow-band emission, was observed by V1 as it approached Saturn along a similar northern-latitude, dayside trajectory (2).

The narrow-band component of SKR resembles the Jovian narrow-band kilometric radiation (nKOM) (8) in a number of ways. Both are confined to frequencies around or below 100 kHz; both have bandwidths of only a few tens of kilohertz and both exhibit polarization-vs-time patterns that are apparently independent of the polarization of the higher frequency bursts. The nKOM is thought to originate from a region near the outer periphery of the Io plasma torus (8), and the Voyager Plasma Science team (9) now reports a plasma torus at Saturn that may provide plasma densities and density gradients in parts of Saturn's magnetosphere that are similar to those encountered in the outer part of the Io torus. Thus, given the apparent similarities between the narrow-band components of radio emission from Saturn and Jupiter and the similarities in certain aspects of their respective plasma environments, we suspect that the two emission components may both originate via similar mechanisms from similar magnetospheric regions. This view has also been advanced in connection with lower frequency, banded emission observed by the V1 Plasma Wave Science instrument at Saturn (10). The Saturnian narrow-band emission seen in Fig. 1 tends to occur at somewhat lower frequencies than does Jupiter's, and this is consistent with the relatively lower electron densities observed in the Saturnian plasma torus/sheet than in the case of the Io torus.

Nearly an hour before closest approach (central pair of panels in Fig. 1) the SKR vanished entirely and did not reappear until about two hours after closest approach. During that interval the only activity we can detect is associated 1) with SED, 2) with the brief, broadbanded ring-plane-crossing event at 0418 SCET and 3) with electrostatic plasma waves at low-order, odd, half-harmonics of the electron gyrofrequency. Thus the SKR source was apparently either occulted or beamed away from the spacecraft when V2 was within about 1 R_S of Saturn's equatorial plane and between 20 and 01 hr local solar time. This 'occultation' is consistent with a northern hemisphere source region (for the RH SKR) near the noon meridian at high latitudes as proposed by Kaiser et al. (6).

When the SKR reappeared at about 0535 SCET on August 26, 1981 the polarization was reversed in sense compared to the pre-encounter interval, and it has remained exclusively LH thereafter. This pattern of RH polarization for SKR observed from above northern latitudes and LH polarization observed from above southern latitudes is exactly what V1 observed (2). LH polarized SKR was detected only during the 23-hr period when V1 was in the southern hemisphere. As before, we associate LH polarized emission with a source in the southern hemisphere. With regard to the intensity of the emission, however, the V2 measurements are distinctly different from what was observed on V1 in that the SKR rapidly drops in intensity and bandwidth soon after its post-encounter reappearance. For example, notice in the lower two sets of dynamic spectra in Fig. 1 that on the first full Saturn rotation after closest approach the low frequency limit of SKR has drifted up to ~200 kHz, and by the end of the last rotation in the figure the few bursts that can be detected are only seen at frequencies between about 500 and 800 kHz. Based on qualitative examination of the LH emission observed by V1 and V2, we conclude that the southern hemisphere source, like the northern hemisphere source, is on the dayside and at high latitudes.

The change in Saturn's kilometer wavelength spectrum is illustrated quantitatively in Fig. 2 which displays the normalized median power flux density for the two Saturn rotations before (labeled V2 INBOUND) and after (V2 OUTBOUND) closest approach. The maximum flux density inbound occurred near 175 kHz, much like the V1 inbound observations (6). The maximum flux density outbound occurs near 500 kHz and is approximately three orders of magnitude weaker than the inbound emission. Also shown in Fig. 2 is the outbound spectrum from V1 (6) that was observed from the conjugate latitude in the northern hemisphere relative to the V2 outbound observations (3.5 hr solar local time, + 26° latitude for V1; ~4.0 hr local time, -27° latitude for V2). Here also we see that the LH, southern hemisphere emission is approximately two orders of magnitude weaker than the RH, northern hemisphere emission.

Three different factors may each contribute to the apparent north-south difference in SKR activity. First, the southern hemisphere SKR may be beamed toward a quite different local time than the northern SKR. This would mean that spectra such as Fig. 2 are from different points on the respective northern and southern SKR emission beam patterns and, thus, make direct comparisons impossible. One of the goals for the V2 encounter, especially during the outbound portion of the trajectory, was to determine the occurrence rate of southern hemisphere (LH) SKR as a function of longitude. Since V1 spent only a brief period south of the Saturnian equatorial plane, it was not possible to determine the longitude profile unambiguously. From the last two panels of Fig. 1 and from more recent data, it appears that the southern hemisphere SKR maximizes approximately 100° in longitude eastward of the northern hemisphere emission. However, although the data appear to be consistent with a dayside source, it is not possible to deduce the exact local time of the source region until a longer span of data is analyzed.

The second possible explanation for the observed north-south radio intensity difference is that the SKR diminished just after closest approach as a consequence of temporal variations in the energy source. In fact, there is some indirect evidence to support this hypothesis. Immediately after the last rotation shown in Fig. 1, SKR was essentially undetectable for two to three days, after which the emission returned and seemed normal. Such an extended period of inactivity is very unusual and may be the result of solar wind pressure variations, as we discuss in greater detail below. However, since a similar north-south radio asymmetry was noted during the V1 encounter (2), it seems unlikely that all of the differences can be attributed solely to coincidental external causes.

Finally, there is the possibility that an intrinsic difference exists between the Saturnian northern and southern radio sources. Intrinsic north-south differences may be associated with differences between the external current systems or between particle entry into the northern and southern SKR source regions. Or, if the radio emission originates in the dayside cusp regions, a long-term periodic difference between northern and southern radio emission properties might exist due to the Saturn-Sun geometry. During the Voyager observations, the flux of solar wind particles into the northern cusp might well be expected to exceed the flux into the southern cusp because the Saturnian northern cusp was tilted toward the sun, by 4° during the V1 flyby and by 7° degrees for V2. At the present time, we conclude that 1) the southern source is intrinsically weaker than the northern source, 2) both sources are located in the sunward hemisphere and 3) substantial long-term (several-day) temporal variations in the activity of the sources occurred shortly after V2 closest approach.

For several months before and for several days after V2 encounter with Saturn, the SKR exhibited temporal variations of a kind never before seen. These fluctuations took the form of well-defined, dramatic decreases in emission activity level, lasting anywhere from about 4 to 8 Saturn rotations (2-3 days) depending on the interval examined. Of those we have studied thus far, the emission intensity dropped below receiver threshold over the entire SKR bandwidth ($\sim$1 MHz) for the duration of the dropout. An example of the beginning of such an event (mentioned earlier) is shown in the last panel of

Fig. 1. Here it is apparent that the SKR has begun to diminish in intensity at a far faster rate than that due to inverse-distance-squared falloff. This diminution continues beyond the last panel in Fig. 1 (not shown) with the result that the SKR falls below receiver threshold at all frequencies for about two days, until reappearing at about 0800 SCET on 29 August. Normalized to an observer-Saturn distance of 1 AU, this threshold represents an emission flux upper limit for the southern hemisphere source of about 10^{-24} W/m^2/Hz (c.f. Fig. 2 for nominal flux levels).

We have identified six similar dropout intervals in the July to August, 1981 V2 data that occurred earlier than the one described here. Since the northern and, to some extent, southern hemisphere sources can be observed before encounter and neither source appears during a cutoff interval, both sources must be affected by the mechanism responsible. Additionally, we have found no comparable dropout periods in the V1 data during the three month period surrounding its encounter in November, 1980. Thus, because this phenomenon appears unique to the Voyager 2 encounter, and in particular since the August 26/27 episode occurred when Saturn's magnetosphere was apparently inflated (11) due to extremely low solar wind flux, we are examining the possibility that the episodes are related to occasions when Saturn is immersed in Jupiter's magnetic tail (12). This interpretation is particularly appealing because, if the SKR emanates from the vicinity of the dayside polar cusps as deduced by Kaiser et al. (6), a strong reduction in solar wind pressure might be expected to diminish the particle population in the cusp region and yield the observed result. If this interpretation is correct, then the time scale of the radio emission turnoff would appear to be approximately two days, since Ness et al. (11) identify the onset of the ram pressure decrease at about 10 hr SCET on 25 August 1981.

If Jupiter's tail or large-scale changes in solar wind pressure should prove effective in extinguishing SKR, it would be the second modulator of Saturn's radio emission. The satellite Dione was first suggested (7,13) as the cause for the disappearance of SKR at times when the radiation should normally be observed. We have made some effort at separating these two effects by taking advantage of the strong frequency dependence of the Dione modulation (7) compared with the very broadband quenching characteristic of the 2-3 day long dropouts. Thus, we were able to examine the 24-day period (1 Aug - 24 Aug) before encounter for evidence of any Dione modulation by eliminating the interval 9/10 Aug, which was clearly a broadbanded, long-term dropout. The result is shown in Fig. 3. Here activity at 59 kHz is organized at Dione's period of revolution (65.7 hr), and heliocentric orbital phase runs from 180° through 360° to 180° for clarity. This histogram is evidence for a strong modulation of the SKR by Dione, and it represents yet another way in which modulation at Dione's period has appeared. Previous reports showed quenching of SKR near 270° Dione phase (7,13) and 40° phase (7). The present analysis, however, reveals not only a shift in the phase of effective quenching to around 180° but also what might be interpreted as a stimulation of activity levels rather than a quenching. This is so because the peak in Fig. 3 is sharper than the 'absorption' minimum by at least a factor of two. The nature of the Dione modulation may become clearer upon examination of the outbound V2 data when the aspect angle of the observations was very different.

SATURNIAN ELECTROSTATIC DISCHARGES

A new phenomenon, Saturn electrostatic discharges or SED, was discovered by the V1 PRA instrument (2,3). An example of SED as they appear on dynamic spectrograms is shown in Fig. 4. SED were also observed during the V2 encounter with Saturn, and many features appear to be the same as before. However, there are also some striking differences.

The SED are again impulsive, lasting for times that vary from 30 ms or less to upwards of 250 ms, and they again appear to be randomly distributed over a frequency range which extends from 100 kHz or less to at least 40 MHz, the highest frequency attainable by the PRA instrument. As before, the SED occurred in episodes lasting several hours. These episodes can be seen in Fig. 5. As before, SED were detected only during the six or seven days surrounding closest approach. This fact, together with the similarities in event duration and frequency distribution suggests that the intensity of SED did not change by any signficant amount between encounters. Although not shown in Fig. 5, SED were detected with V2 more than 48 hr before the first inbound bow shock crossing, and so they are clearly not due to in-situ phenomena occurring at the spacecraft inside the Saturn magnetosphere.

In contrast to these similarities, the rate of occurrence of SED impulses at the second encounter was only about 1/3 of that at the first. Comparison of panels in Fig. 4 illustrates this difference. In addition, the episodes themselves were distributed much more symmetrically about the time of Saturn closest approach than was the case for V1, when they occurred mostly after encounter.

During V1 pre-encounter and closest approach fewer than 1% of the SED events were polarized whereas during post-encounter 90 to 95% of the events above 15 MHz were polarized in the LH sense (3). Furthermore, the proportion of polarized events diminished with decreasing frequency. During the V2 encounter, however, most of the polarization occurred in channels below 5 MHz. Approximately, 5 to 10% of the events in these channels displayed polarization, with roughly as many in the RH sense as in the LH sense. This pattern remained more or less invariant throughout the entire encounter. Thus, V2 data confirm recognizably the same SED phenomenon, but the striking differences in polarization, episode distribution and number of events strongly suggest a source that changes with time.

An analysis of the V2 data yields a repetition period of SED episodes of $10^h11^m \pm 5^m$, which is consistent with the $10^h10^m \pm 5^m$ period found with the V1 data (3) and clearly different from the $10^h39.4^m \pm .1^m$ Saturnian rotation period (5). The phase of the repetition period is fixed relative to the observer-planet line implying that the source of SED rotates (or revolves) like a searchlight and is not fixed relative to the sun as is the case for SKR. We had previously concluded (2,3) that the repetition rate of SED episodes and the searchlight behavior implied that the source of SED is not similar to the SKR source. Also, the observation of SED bursts at frequencies well below the Saturnian ionosphere plasma frequency virtually eliminates any sort of atmospheric phenomenon as the cause of SED. This information, combined with the 10^h10^m period, led us to conclude (2,3) that the source of SED was in the ring system at a radial distance of about 1.81 R_S from the center of the planet. The V2 observations reported here in no way change our original thesis.

RING PLANE EVENT

The PRA instrument on V2 also detected an intense event at or near the time of ring-plane crossing (Figs. 4 and 6). Power in the PRA channels peaked at spacecraft event time of 0418:17 on day 238 (August 26, 1981). The spacecraft distance from Saturn at ring-plane crossing was approximately 2.88 R_S, near to the nominal 2.82 R_S location of the G-ring.

The time profile of the PRA event was generally symmetric about the peak. The central peak displays a half-power rise time of 6 sec or less and the overall pattern exhibits a 30-dB rise time of approximately 1 minute. These times correspond to distances of about 70 km and 700 km, respectively, normal to the ring plane. At its peak, the ring plane event extended from frequencies of 10 Hz or less to approximately 1 MHz, and the spectrum peaked in the 56 Hz channel of the Plasma Wave Science instrument (14). The spectral density over five decades in frequency is shown in the Fig. 6 inset. The emission showed no evidence of polarization in any of the PRA channels.

A similar event may have occurred at the time of the outbound ring plane crossing of V1 (15); however, the essential features of that event are difficult to extract because of the presence of strong plasma wave phenomena and SKR emissions.

The ring plane event is entirely distinct from both SKR and SED in onset, duration, spectral character, and polarization (2-4). The associated mechanism, we presume, must also be distinct. In particular, the plasma instrument on V2 measured a nominal plasma concentration of approximately 100 particles/cm^3 during the ring plane crossing (9); thus, the ambient plasma frequency was at least 100 kHz, which is well above the frequency at which the event spectrum peaked. Therefore, the observed emissions evidently are not propagating electromagnetic disturbances that have an origin either at Saturn or in any of its rings including, in particular, the G-ring. On the contrary, the phenomenon appears to have an origin local to the spacecraft.

Warwick et al. (2) suggested that charged dielectric particles striking the PRA antenna booms could generate electrical events. Micron-size ice particles striking the spacecraft at relative velocities of 10 km/sec or more will most likely vaporize and ionize. The typical particle sizes in the G-ring are believed to be on the order of 1 to 5 μ (16) and Clark (17) deduced that the composition of ring material in general is approximately 95% water ice and 5% ferric oxide. The spacecraft velocity relative to G-ring material was about 14 km/sec at the time of ring plane crossing.

We propose the following simple model of the ring-plane event. At or about the time of ring plane crossing, V2 strikes charged micron-size ice particles in the outer regions of the G-ring. The 56 Hz spectral peak is taken to be an approximate measure of the impact frequency. Each impact produces a tenuous charged plasma enveloping a part or all of the spacecraft. The plasma dissipates due to thermal motion and to relative motion between the spacecraft and Saturn's corotating magnetic field in which the plasma becomes embedded. Typical dissipation times are on the order of 0.5 ms. Since this is short compared to the assumed impact frequency, the phenomenon is dominated by single events. The step-function increases in voltage associated with the production of charged plasma exhibit an f^{-2} flux density spectrum; however, such a spectrum is modified at low frequencies by the impact rate itself and at high frequencies by dissipation effects and plasma physical phenomena. Additional modifications could result from spacecraft interactions with the plasma. Therefore, an impact discharge phenomenon could produce a spectrum like that shown in Fig. 6.

In this model the V2 PRA and Plasma Wave Science instruments acted in tandem to yield in situ measurements of G-ring material. The fall-off in intensity and change in spectrum away from the ring plane is attributed to variations in particle size and number density along the path of the spacecraft. The total vertical thickness of ~ 1500 km inferred from the duration of the ring-plane noise event is much greater than the optical thickness reported for any of Saturn's major rings. Hence, these data seem to indicate that the G-ring possesses a tenuous halo that extends well beyond the nominal ring particle layer — much like the E-ring with its 1800 km inferred thickness (18).

FIGURE CAPTIONS

Fig. 1. Dynamic spectra of kilometer wavelength radio emissions observed during the five consecutive 10.66-hr rotations of Saturn centered on the time of Voyager-2 closest approach. The panels are aligned with respect to sub-solar Saturn longitude, and each panel is formed from averages over 1° increments of longitude (1.8 min.) at each of 70 frequency channels spaced at 19.2 kHz intervals between 1.2 and 1326 kHz. (a) Total intensity encoded so that increasing darkness denotes increasing intensity; (b) dominant sense of circular polarization encoded so that gray denotes right-hand polarization and black denotes left-hand polarization. Notice near the time of closest approach (C.A.) and ring-plane crossing (middle panels) that the Saturnian kilometric radiation disappears, and only very low frequency in-situ plasma waves and the ring-plane burst are detected. Brief polarization reversals occur during spacecraft rolls when Saturn moved to the opposite hemisphere relative to the plane of the PRA antennas, and a major right-to-left-hand reversal occurred after closest approach when Voyager-2 moved from northern to southern latitudes. Also noted in the plots are the times when a 15 dB attenuator was inserted in the receiver pre-amp and when some non-Saturnian signals (solar type III bursts and spacecraft radio frequency interference) were observed.

Fig. 2. Spectra formed from the median values of power flux density observed over the period before Voyager-2 closest approach (V2 inbound) covered by the top two panels in Fig. 1(a) and the period after Voyager-2 closest approach (V2 outbound) covered by the bottom two panels in Fig. 1(a) and for the month after Voyager-1 closest approach (dashed curve). The V2 inbound and V1 outbound data are both dominated by the right-hand (RH) polarized emission observed from northern latitudes, and the V2 outbound spectrum is due to left-hand (LH) polarized emission observed from southern latitudes. All flux densities are normalized to an equivalent observer-Saturn distance of 1 AU.

Fig. 3. Histogram showing the control of the SKR by satellite Dione during the interval from August 1 through 24. Data are organized in heliocentric Dione phase, running from 180° to 180° for clarity. The histogram is comprised of events recorded at 59 kHz and includes only events with flux density exceeding 2×10^{-21} $W/m^2/Hz$ for an observer situated 1 AU from Saturn in order to eliminate inverse-distance-squared bias.

Fig. 4. Dynamic spectra of observations obtained between 1.2 kHz and 40.5 MHz with 6-sec time resolution over 1-hr intervals spanning the outbound ring-plane crossing by Voyager-1 at a distance of 6.3 R_S (upper panel) and the ring-plane crossing by Voyager-2 at a distance of 2.9 R_S (lower panel). SED appear as bursts lasting less than 1 sec that occur at whatever frequency the receiver was tuned to at the instant they occur. Notice that 1) the SKR is evident below 1 MHz during the V1 ring plane crossing segment but not for V2, 2) the brief ring plane burst extends up to above 1 MHz for V2 but is not conspicuous for V1, and 3) the SED bursts are much less frequent for V2 than for V1.

Fig. 5. Figure shows the organization of SED into distinct episodes separated by about 10 hour. Note that the SED were observed several days prior to V2 entry into the Saturnian magnetosphere. The number of SED clearly maximize near closest approach.

Fig. 6. Plots of relative intensity measured at 13 selected frequency channels between 1.2 and 1000 kHz during the time of the Voyager-2 crossing of the ring plane. The inset shows the field intensity spectrum measured at the peak of the ring plane event (0418 SCET) by the PRA instrument and by two channels of the Plasma Wave Science instrument (14).

REFERENCES

1. The PRA instrument utilizes a pair of orthogonal, 10-m, monopole antennas and a 198-channel step-frequency receiver to measure the intensity and sense of circular polarization of radio signals between 1.2 kHz and 40.5 MHz. For more details see J. W. Warwick et al., Space Sci. Rev. 21, 309 (1977).

2. J. W. Warwick et al., Science 212, 239 (1981).

3. D. R. Evans, J. W. Warwick, J. B. Pearce, T. D. Carr, J. J. Schauble, Nature 292, 716 (1981).

4. M. L. Kaiser, M. D. Desch, J. W. Warwick, J. B. Pearce, Science 209, 1238 (1980).

5. M. D. Desch and M. L. Kaiser, Geophys. Res. Lett. 8, 253 (1981).

6. M. L. Kaiser, M. D. Desch, A. Lecacheux, Nature 292, 731 (1981).

7. M. D. Desch, M. L. Kaiser, Nature 292, 739 (1981).

8. M. L. Kaiser and M. D. Desch, Geophys. Res. Lett., 7, 389 (1980).

9. H. S. Bridge et al. Science, this issue.

10. D. A. Gurnett, W. S. Kurth and F. L. Scarf, Nature, 292, 733 (1981).

11. N. F. Ness et al. Science, this issue.

12. F. L. Scarf et al., Nature, 292, 585 (1981).

13. W. S. Kurth, D. A. Gurnett, F. L. Scarf Nature, 292, 742 (1981).

14. F. L. Scarf et al., Science, this issue.

15. B. M. Pedersen et al. Nature 292, 714 (1981).

16. R. J. Terrile, private communication (1981).

17. R. N. Clark, Icarus 44, 388 (1980).

18. D. H. Hume, R. L. O'Neal, W. H. Kinard, J. M. Alvarez, Science, 207, 443 (1980).

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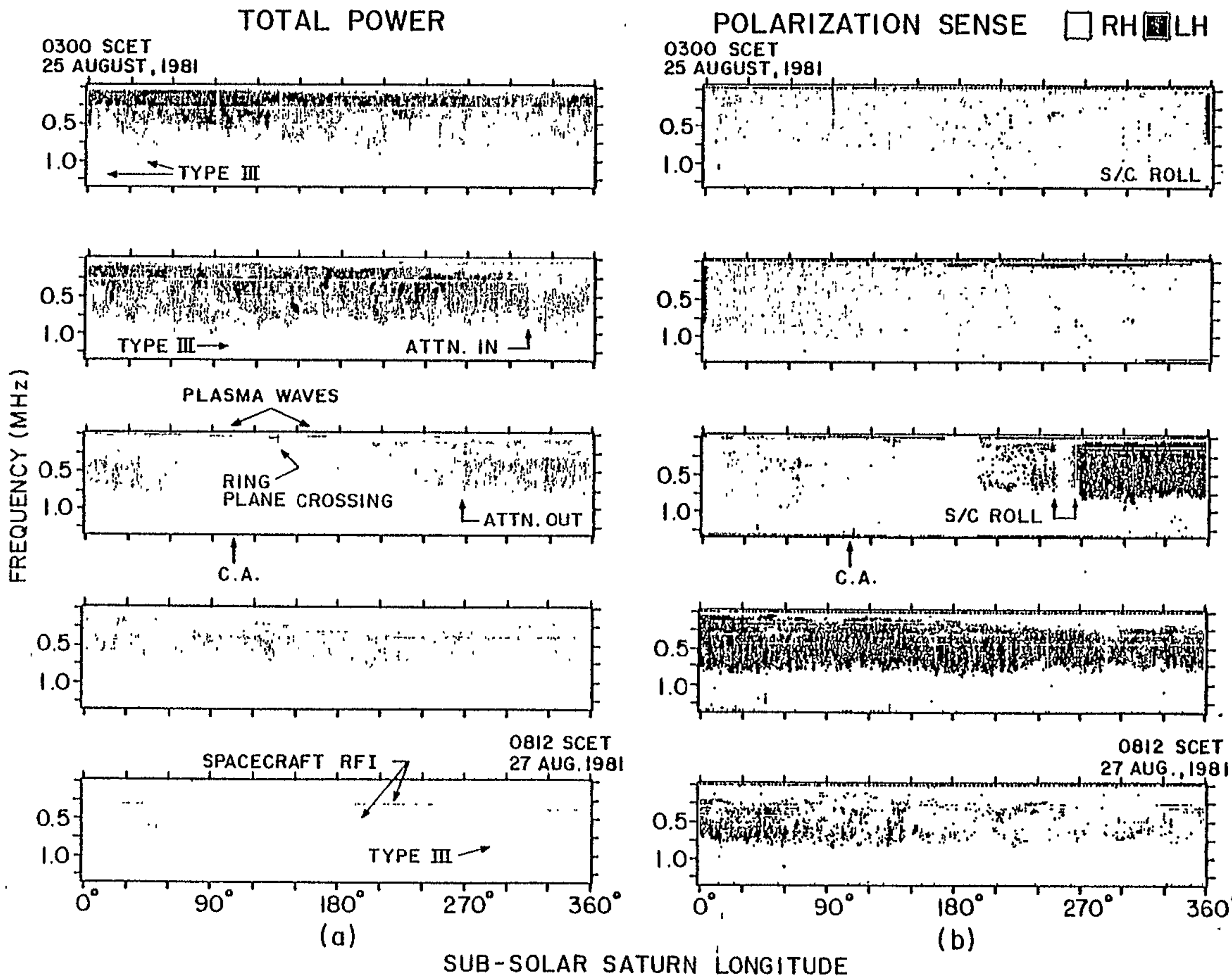
J. W. Warwick, D. R. Evans, J. H. Romig,
Radiophysics, Inc.
Boulder, Colorado 80301

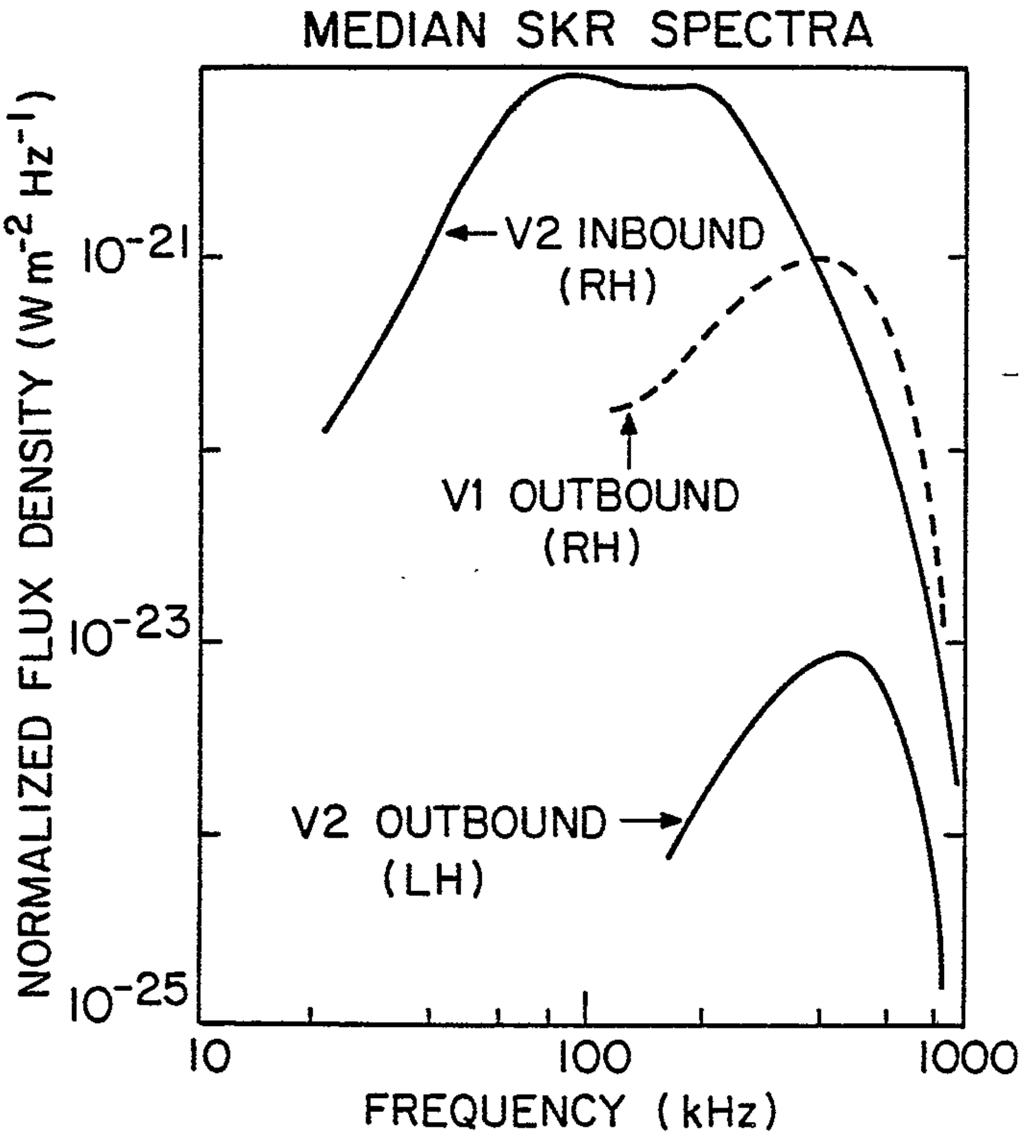
J. K. Alexander, M. D. Desch, M.L. Kaiser
Laboratory for Extraterrestrial Physics
Goddard Space Flight Center
Greenbelt, Maryland 20771

M. Aubier, Y. Leblanc, A. Lecacheux, B. M. Pedersen
Observatoire de Paris
Section d'Astrophysique de Meudon
92190 Meudon, France



TOTAL POWER
POLARIZATION SENSE
RH
LH
0300 SCET
25 AUGUST, 1981
0.5
1.0
TYPE III
S/C ROLL
ATTN. IN
PLASMA WAVES
RING
PLANE CROSSING
ATTN. OUT
C.A.
FREQUENCY (MHz)
SPACECRAFT RFI
0812 SCET
27 AUG. 1981
0°
90°
180°
270°
360°
(a)
(b)
SUB-SOLAR SATURN LONGITUDE

Figure 1



MEDIAN SKR SPECTRA
NORMALIZED FLUX DENSITY (W m^{-2} Hz^{-1})
10^{-21}
10^{-23}
10^{-25}
V2 INBOUND
(RH)
V1 OUTBOUND
(RH)
V2 OUTBOUND
(LH)
10
100
1000
FREQUENCY (kHz)

Figure 2

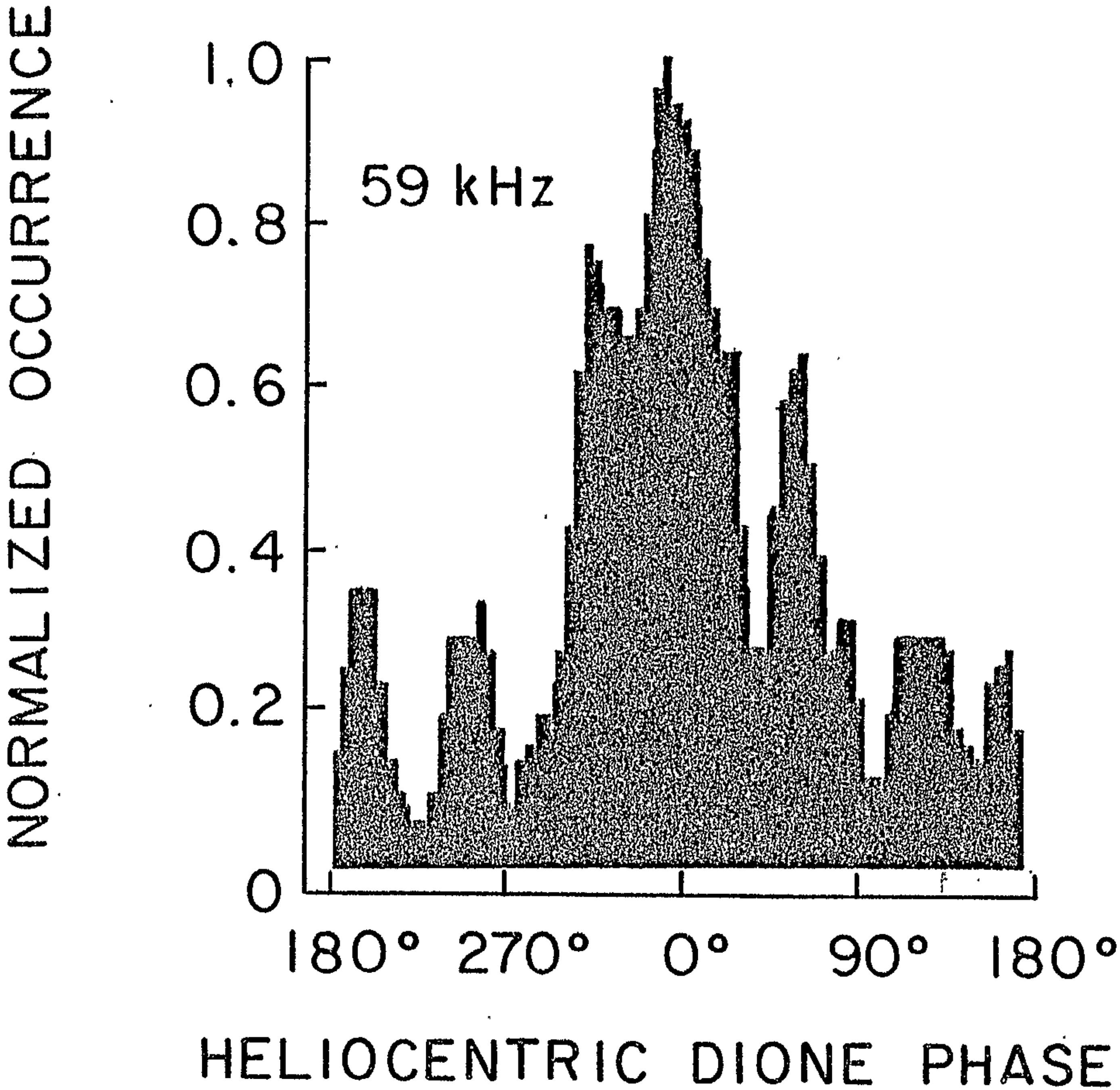

NORMALIZED OCCURRENCE
1.0
0.8
0.6
0.4
0.2
0
59 kHz
180° 270° 0° 90° 180°
HELIOCENTRIC DIONE PHASE

Figure 3

ORIGINAL PAGE IS
OF POOR QUALITY

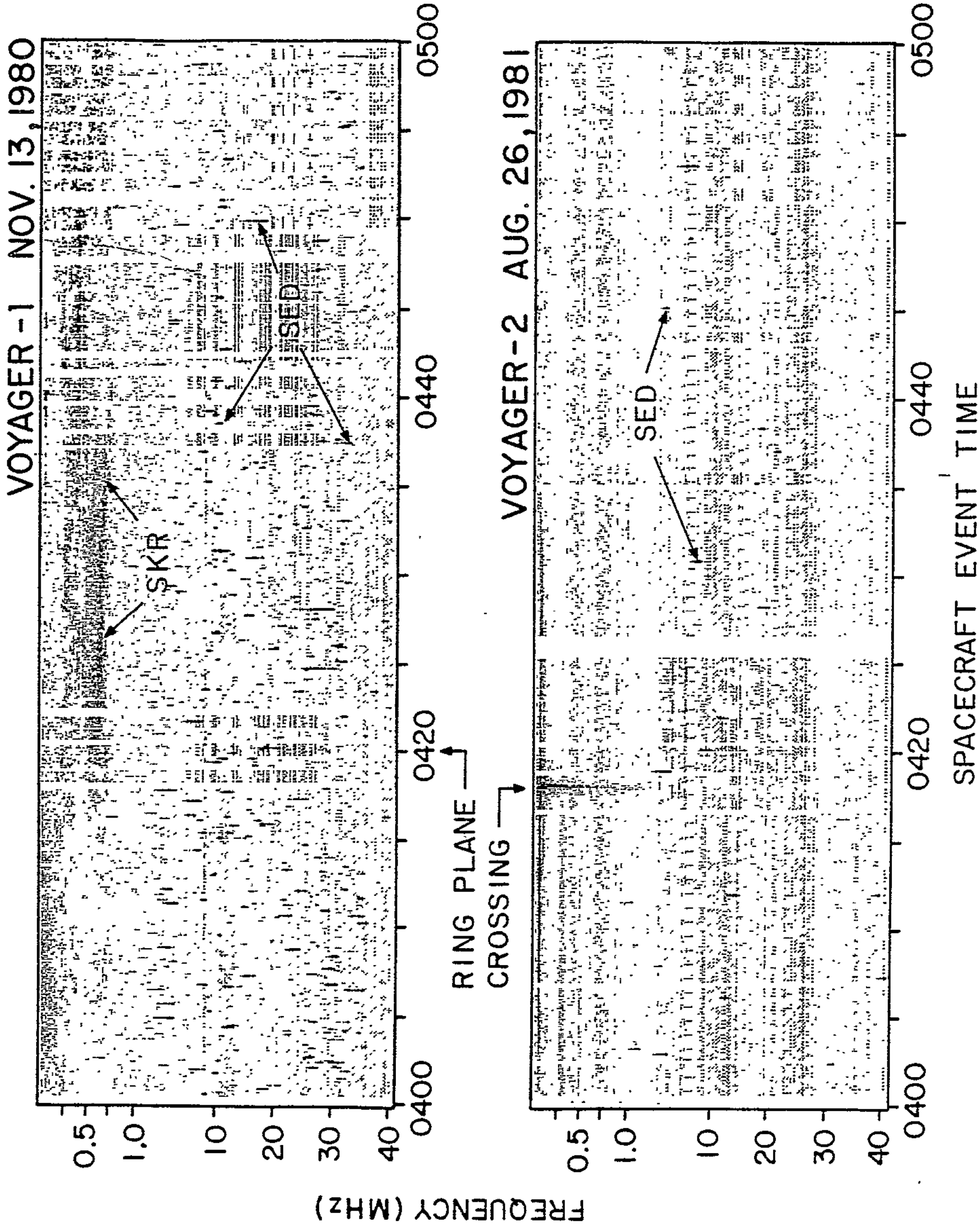


Figure 4

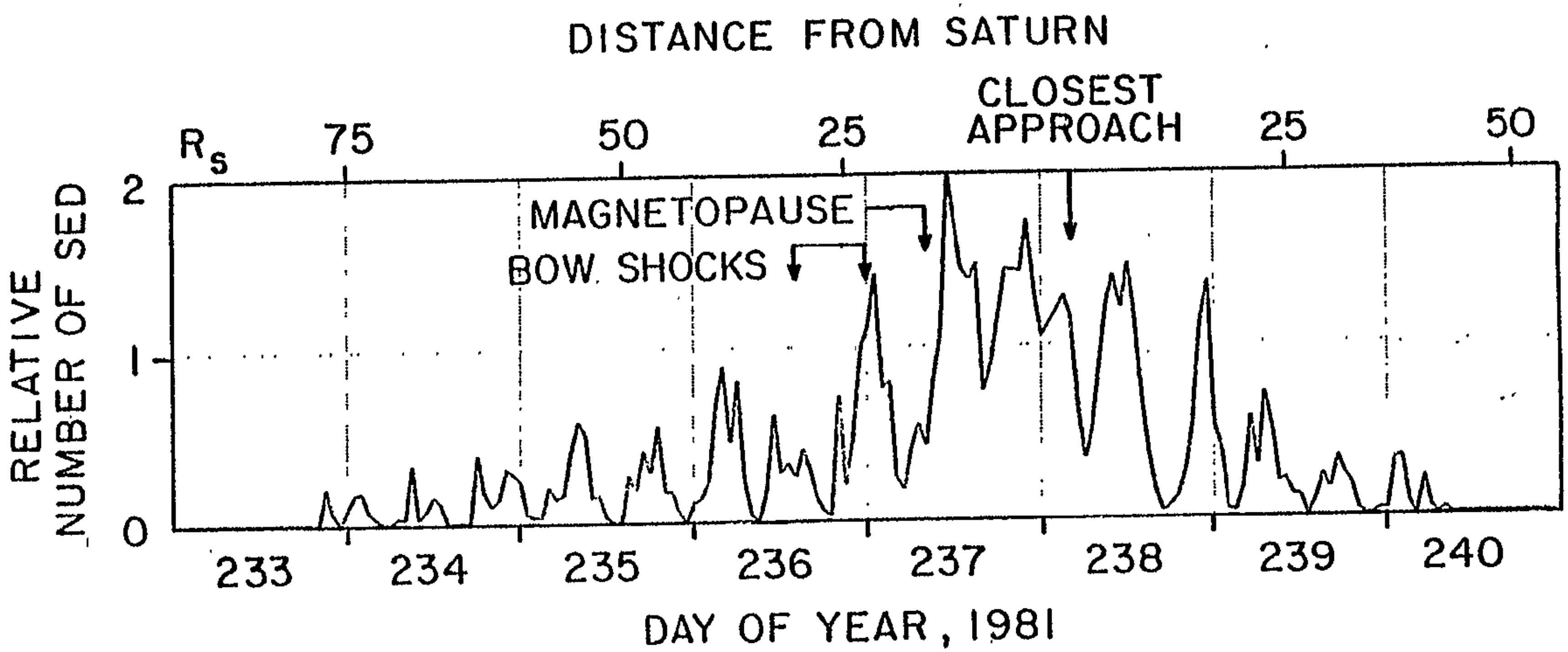
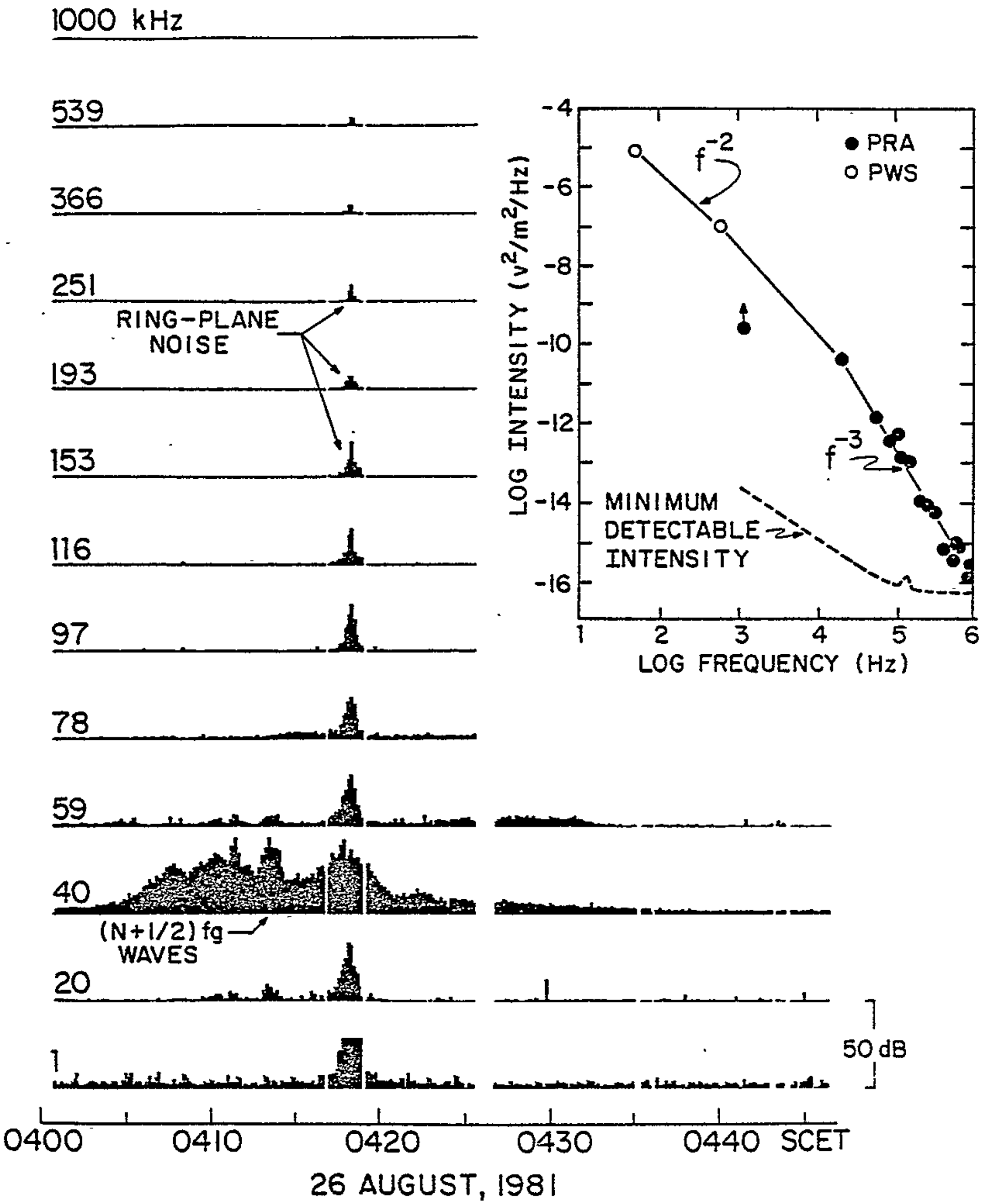

DISTANCE FROM SATURN
CLOSEST APPROACH
R_S
75
50
25
25
50
MAGNETOPAUSE
BOW SHOCKS
RELATIVE NUMBER OF SED
2
1
0
233
234
235
236
237
238
239
240
DAY OF YEAR, 1981

Figure 5



1000 kHz
539
366
251
RING-PLANE NOISE
193
153
116
97
78
59
40
(N+1/2) fg WAVES
20
1
50 dB
0400
0410
0420
0430
0440
SCET
26 AUGUST, 1981
LOG INTENSITY (V²/m²/Hz)
LOG FREQUENCY (Hz)
PRA
PWS
f⁻²
f⁻³
MINIMUM DETECTABLE INTENSITY

Figure 6

BIBLIOGRAPHIC DATA SHEET

1. Report No. TM 83856	2. Government Accession No.	3. Recipient's Catalog No.
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16. Abstract Voyager-2 Planetary Radio Astronomy measurements obtained near Saturn have added further evidence that Saturnian kilometric radiation (SKR) is emitted by a strong, dayside source at auroral latitudes in the northern hemisphere and by a weaker (by more than an order of magnitude) source at complementary latitudes in the southern hemisphere. These emissions are varaible both due to Saturn's rotation and, on longer time scales, probably due to influences of the solar wind and the satellite Dione. The Saturn electrostatic discharge bursts (SED) first discovered by Voyager-1 and attributed to emissions from the B-ring were again observed with the same broadband spectral properties and a $10^h 11^m \pm 5^m$ episodic recurrence period but with an occurrence frequency of only about 30% of that detected with Voyager-1. During the crossing of the ring plane at a distance of 2.88 R_S, an intense noise event extending up to above 1 MHz was observed for about 150 sec. This event is interpreted to be a consequence of the impact/vaporization/ionization of charged micron-size G-ring particles distributed over a total vertical thickness of about 1500 km.

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