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Radio Emission Signature of Saturn Immersions in Jupiter's Magnetic Tail

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RADIO EMISSION SIGNATURE OF SATURN IMMERSIONS IN JUPITER'S MAGNETIC TAIL

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Abstract. During the interval from about May through August 1981, when Voyager 2 was inbound to Saturn, the Planetary Radio Astronomy instrument measured repeated, dramatic decreases in the intensity of the Saturn Kilometric Radiation (SKR). The emission dropouts averaged two orders of magnitude below mean energy levels and varied from about 1 to 10 Saturn rotations in duration. Comparison with pre-Saturn encounter Voyager 1 observations (June to November, 1980) shows that the SKR dropouts were unique to the Voyager 2 observing interval, consistent with the closer proximity of Saturn to Jupiter's distant magnetotail in 1981. Further, the dropouts occurred on the average at times when Voyager 2 is known to have been within or near Jupiter's magnetic tail. Interpretation of these events as the radio signatures of successive Saturn immersions into Jupiter's tail or wake region is consistent with the independent evidence that the SKR radio source is driven externally by the solar wind ram pressure. The dropouts are identical to the one observed just after Voyager 2 closest approach to Saturn, providing the best evidence that Saturn was within Jupiter's tail at the time of the encounter. The sequence of events during this Saturn tail encounter is deduced.

to appear in JGR

Introduction

Scarf [1979] first pointed out that the trajectory taken by Voyager 2 (V2) between Jupiter and Saturn was such that the spacecraft might encounter the Jovian magnetotail or wake region 7000 to 8000 R_j downstream of Jupiter. Subsequent observations by Kurth et al. [1982a] and Lepping et al. [1982,1983 and references therein] confirmed this prediction. Instruments on V2, measuring radio waves, plasma, and magnetic fields upstream of Saturn, detected nonthermal continuum emission, extremely low density plasma, and magnetic field magnitudes and directions characteristic of a magnetotail and wake connected to Jupiter. About a dozen major encounters of V2 with Jupiter's magnetotail were detected, lasting from about 1 to 10 days in duration, with six of the events occurring in the interval January to June, 1981. V2 was between about 5000 and 8000 R_j dowstream of Jupiter when the principal encounters occurred.

A separate but related issue raised by Scarf [1979] and also by Grzedzielski et al. [1981] concerned the potential immersion of Saturn's magnetosphere into Jupiter's tail, possibly even during the time of the V2 encounter with Saturn in August, 1981. This prediction has been much more difficult to confirm empirically. Grzedzielski et al. showed that a Saturn encounter with Jupiter's tail was likely in view of the model Jovian tail they derived, which had a length of 7-15 AU and a width at Saturn of 0.6 AU. The observable effects predicted by Grzedzielski et al., should such an immersion take place, included a major inflation of the Saturnian magnetosphere, accompanied by a flare up in the Saturn Kilometric Radiation (SKR) as the magnetosphere experienced pressure gradients at the tail boundary crossings.

A number of observations made onboard V2 during the encounter suggested the possibility that the Jovian tail did engulf Saturn's magnetosphere shortly before closest approach, and that Saturn remained in the tail for some time afterward [see also Lepping et al., 1983]. Ness et al. [1982] reported an inflation of the magnetosphere, commencing at hour 10 of day 237, when the magnetic field orientation rotated sunward. They suggested that this might have occurred in response to a sudden decrease in solar wind ram pressure. Nearly simultaneously, Vogt et al. [1982] recorded a major increase in energetic charged particle fluxes. Shortly after this time, both Warwick et al. [1982] and Scarf et al. [1982] observed a sharp decrease in the intensity of the SKR that endured for several days. They interpreted this as possibly due to a tail encounter. Evidence of a statistical nature was provided by Bridge et al. [1982] who studied the past history of ram pressure variations at Saturn. They concluded that only 3% of the time does the solar wind ram pressure reach values low enough to explain the enlarged outbound magnetosphere that was observed. Finally, Kurth et al. [1982b] reported the detection of nonthermal continuum within Saturn's magnetosphere and suggested that some of it was possibly of Jovian origin. Summarizing the observations, Lepping et al. [1983], however, concluded that the evidence to date for a tail immersion during the V2 encounter period was indirect. Lacking observations in the interplanetary medium near Saturn, it has been difficult to show conclusively that what was observed during the V2 encounter might not have been due simply to rather unusual solar wind conditions.

Using the SKR as a remote diagnostic of conditions within Saturn's magnetosphere, we show in this paper that Saturn did indeed experience repeated immersions into Jupiter's tail during the period from April through August, 1981. During each Saturn immersion, unprecedented decreases in radio emission levels occurred, with power often dropping below receiver detection threshold for many hours at a time. This behavior is opposite to that predicted by Grzedzielski et al. [1981], but consistent with the fact that the SKR is modulated by the solar wind ram pressure [Desch, 1982; Desch and Rucker, 1983]. The dropout signature is further used to show that Saturn was inside the Jovian magnetotail during the V2 encounter in August, 1981. The sequence of events during Saturn's tail immersion is deduced from a comparison of several experiments on Voyager 2.

Observations of SKR Dropouts

Figure 1 shows frequency-time dynamic (total power) spectrograms of SKR activity for three days between June 28 (day 179) and July 3 (day 184), 1981. Each spectrum covers the frequency range from 20 to 1320 kHz for a 24-hr interval. These are Voyager 2 data, taken when the spacecraft was about 0.35 AU from Saturn and 3.5 AU from Jupiter. Except for a frequency-drifting solar type III burst at 0430-0450 spacecraft event time (SCET), all of the emission visible on day 179 in panel (a) is SKR. The activity level is about as near to continuous as SKR has been observed and the intensity level is higher than normal. This period of time is contrasted with that two days later, shown in panel (b), when the emission intensity has dropped significantly. A few very weak Saturn bursts appear around 0700 and 2000 SCET, but the emission level has clearly declined compared with the interval on day 179. The other emission episode apparent in panel (b) is an hour-long narrow band event centered at 1800 SCET and 80 kHz. It is probably associated with the plasma-sheet boundary emissions described by Gurnett et al. [1981] and is not SKR. By day 184 (panel (c)), SKR is not detected above receiver detection threshold for many hours at a time. Note that no SKR is observed from 0 to 1000 SCET, nor is any observed from 1015 to 1700 SCET. Abruptly at 1700 SCET on this day, SKR returns to intensity levels comparable to those on day 179.

To examine these intensity variations more quantitatively, an 18-day period of time encompassing the spectra of Figure 1 is shown in Figure 2. Here, the SKR energy level in joules/rotation (J/rot) is plotted relative to the receiver detection threshold (dashed line). The energy is computed by integrating the observed radio flux over both the SKR emission bandwidth and over one Saturn rotation (10.66 hr). An isotropically radiating source is assumed.

For comparison with the SKR energy profile, the start and stop times of a low plasma density event observed by the Plasma Science (PLS) experiment is also shown. This is one of the events, described by Kurth et al. [1982a] and Lepping et al. [1983], identified as an interplanetary signature of the entry of Voyager 2 into Jupiter's magnetic tail. During these events the spacecraft does not measure solar wind plasma per se because the solar wind is excluded from the magnetic tail region. What are observed instead are the very low plasma densities and pressures associated with the downstream tail and wake regions. The low density event is coded such that the unfilled, hashed, and filled bars indicate upper-limit plasma densities at the spacecraft of 0.05, 0.03 and 0.01 cm^{-3}, respectively. Densities below 0.03 cm^{-3} represent extremely low values, and the density on day 185 drops to about 0.004 cm^{-3}.

The association of the 6.5-day low density event with the 4-day SKR dropout is clear. The SKR energy level varies substantially, but remains between 2×10^{12} and 5×10^{13} J/rot except for the 4-day period centered on day 183. Over this 4-day period SKR energy drops below 10^{12} J/rot, and for two rotations, namely those centered on days 182.22 and 184.14, no radio emission is observed above the PRA detection threshold, which is about 3×10^{10} J/rot at this time. The onset of the SKR dropout is nearly simultaneous with the start of the PLS low density event. No emission is observed above receiver detection threshold during the hashed ($<.03$ cm^{-3}) and shaded ($<.01$ cm^{-3}) plasma intervals. Subsequently the emission returns to normal levels, but it does so well before the end of the low density plasma event. As will be shown below, the near simultaneous onset of the SKR and plasma density dropouts and the apparently premature return of the SKR to normal levels is fairly representative of the SKR dropouts examined in this study.

In comparing the timing of the SKR dropout and the low density event of Figure 2, no correction was made for the location of Voyager 2 relative to Saturn. Indeed, since the nature of the magnetotail geometry and motion are not well understood, an exact correction is impossible at this time. It is not known, for example, whether the tail simply expands into low solar wind density regions or if it also executes a flapping motion, although the former is expected to dominate [Lepping et al., 1983]. In addition, the presence of individual tail filaments cannot be accounted for adequately. However, the expected solar wind propagation time from V2 to Saturn is on the order of one day on day 185. This is much less than the ~7 day duration of the event and so the timing correction is probably not an important factor for this event.

To investigate the long-term history of the dropouts, a survey plot of SKR energy output measured by Voyager 2 is shown in Figure 3. The 135-day interval extends from April 20 to September 1, 1981 (days 110 - 244) and includes the Saturn encounter period (day 238). The minimum detectable energy, indicated by the dashed line, decreases with time in proportion to the inverse square of the spacecraft-Saturn distance. As was the case for the event in Figure 2, the radio source energy output remains at levels in excess of about 7.5×10^{11} J/rot most of the time. When the emission drops below this level, as indicated by the shaded intervals, it does so dramatically, falling to the receiver detection threshold in every case except for the last two episodes. Since the most often observed (modal) intensity level throughout this interval is about 10^{13} J/rot, these dropouts represent energy decreases of over two orders of magnitude on the average. Notice that enhancements above the modal energy level, on the other hand, only twice exceed one order of magnitude.

The $7.5\text{x}10^{11}$-J/rot breakpoint between normal and dropout SKR emission levels was derived from an occurrence-frequency histogram of the events in Figure 3. This energy distribution was characterized by a maximum number of events, or rotations, having energies near 10^{13} J/rot, a minimum number of rotations having energies in the range $5\text{x}10^{11}$ to 10^{12} J/rot, and a sharply increasing number of events with energies below $5\text{x}10^{11}$ J/rot. Thus the distribution is bimodal with a broad minimum from about $5\text{x}10^{11}$ to 10^{12} J/rot. Therefore, although there is some flexibility in assigning the energy level that actually constitutes an SKR dropout, it is clear from Figure 3 that varying the breakpoint between $5\text{x}10^{11}$ to 10^{12} would not significantly affect the dropout identifications.

In order to emphasize the uniqueness of the dropouts seen in Figure 3, the SKR energy observed by Voyager 1 during its pre-encounter approach to Saturn is shown in Figure 4. The V1 spacecraft-Saturn geometry was very similar to that of the Voyager 2 approach to the planet, and both spacecraft were observing the same (northern- hemisphere, right-hand polarized) radio source during their respective approach intervals. Examination of Figures 3 and 4 shows that the gross statistical properties of the SKR energy as observed by Voyagers 1 and 2 are very similar. For example, the modal energy value observed by Voyager 1 was, like the Voyager 2 value, about 10^{13} J/rot. Also, both samples have maxima slightly in excess of 10^{14} J/rot. The Voyager 1 data, however, show none of the dropout signatures so evident in the Voyager 2 data. In fact, as observed by Voyager 1, the SKR emission level never dropped below 10^{12} J/rot during the entire 140-day interval plotted in Figure 4. Thus on a rotation-averaged basis, the SKR energy remained well above threshold levels during the 4.5-month interval before Voyager 1 encounter with Saturn. But during the Voyager 2 approach, the SKR energy fell to or nearly to threshold level on eight occasions within 135 days.

The reason for this radically different behavior between V1 and V2 observations is suggested by the trajectory geometry. Although the spacecraft-Saturn geometries were very similar, the trajectories relative to the Jupiter-sun line were quite different. As Scarf [1979] pointed out, Saturn passed much closer to this line, and hence closer to the nominal location of Jupiter's distant tail, during the interval of time when V2 was making observations in 1981 than when V1 was observing Saturn in 1980. During the V2 analysis interval, Saturn was never more than about 9.5 deg from the ecliptic-projected Jupiter-sun line and, in fact, crossed this line in May-June, 1981. But during the V1 interval shown in Figure 4, Saturn was between 19 and 32 degrees from this line. (Angles are measured with Jupiter at the vertex.) The observations shown in Figures 3 and 4 are thus consistent with the SKR dropouts being due to immersions of Saturn into Jupiter's tail. This is the behavior one would expect of the SKR source since it is known that the SKR is driven by the solar wind ram pressure [Desch and Rucker, 1983] which is extremely low inside the magnetotail.

The observations also suggest that Jupiter's magnetotail is confined to a certain angular limit from the Jupiter-sun line. As mentioned, no SKR dropouts were observed over the duration of the V1 analysis interval, during which time Saturn was between 19° and 31° from the Jupiter-sun line. Only when Saturn was within about 10° of this line, that is during the V2 observing interval, were dropouts observed. Some tentative dropouts were observed as early as day 78 of 1981 (not shown in Figure 3), but Saturn was less than 10° from the Jupiter-sun line at this time also. It would appear then that Jupiter's tail is limited to ±10-20° excursions from this line at Saturn's distance from Jupiter. This range brackets the 12° limit set by Lepping et al. [1983].

Comparison with Plasma Observations

While this constitutes a good plausibility argument for the reasons behind the uniqueness of the dropouts evident in the V2 data, the association of the SKR dropouts with the tail events detected in situ by Voyager 2 has yet to be shown. In Figure 2 it was evident that the SKR dropout centered on day 183 coincided extremely well with the PLS low density event observed at Voyager 2. To assess how well the SKR dropouts

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and low density events are associated in general, a superposed epoch analysis was performed taking the start time of each SKR dropout as the zero epoch. The start time was defined as the first rotation with energy below 7.5×10^{11} J/rot. Each of the episodes shown in Figure 3 was used, except for the last one, which occurred during Saturn encounter and for which no interplanetary plasma observations are possible. The plasma densities were also superposed, using the time of the SKR zero epoch to align the low density events. Plasma densities are from Lepping et al. [1983, see, e.g., their Figure 4].

The results of the analysis are shown in Figure 5. Superposing the data in this way tends to smooth out details that might otherwise be evident in individual comparisons. In addition, as explained earlier, no timing corrections were made for the location of Voyager relative to Saturn. In spite of these smoothing effects, several of the features that were apparent in Figure 2 are also clearly shown here. First, it is evident that the low plasma densities seen by V2 when it entered Jupiter's tail and wake are associated with the SKR dropouts. Second, the onset of the SKR dropouts, which takes place in Figure 5 at about 1.75 days before the zero epoch, occurs less than 1 day after the onset of the plasma density decline (~2.5 days). Third, the minimum in the SKR energy precedes the minimum in the plasma density. For the day 183 event shown in Figure 2, the centroid of the SKR dropout also preceded the plasma density 'core event', but only by about 1 day. In the superposed epoch analysis of Figure 5, the offset is about 3 days. Finally, the SKR recovers to nominal energy levels well before the low density event ends as seen at the spacecraft.

The precise sequence of events depicted here varies somewhat from episode to episode; however, the qualitative features shown in Figure 5 are representative of a 'typical' event. In general there is a close association between the V2 Jovian magnetotail events and the disappearance of the Saturn radio source. Onsets coincide more nearly than stop times, and the center times of the SKR dropouts precede the plasma density core times. Finally, the radio emission level recovers to pre-dropout levels well before the tail event ends as seen at the spacecraft.

Saturn Encounter Episode

The last SKR dropout seen in Figure 3 is the 'disappearance' episode that occurred near day 240 during the V2 encounter with Saturn. It was described by Warwick et al. [1982] and Scarf et al. [1982], who suggested that the disappearance might have been due to Saturn's being immersed in Jupiter's tail at some time during the encounter. The observations reported in this paper confirm this. Just as were the seven dropout episodes preceding it, the SKR dropout observed during the Saturn encounter was certainly caused by an immersion of Saturn into Jupiter's tail. The encounter episode was as pronounced an emission decrease as any of the dropouts observed during the preceding 120 days. This episode was also one of the longest tail encounters; although, as will be shown, the precise timing of this event is complicated by several factors. Note also that while the emission level declined three orders of magnitude in energy emitted per rotation (Figure 2), it did not reach detection threshold, and therefore is not actually a complete disappearance as originally reported.

The Introduction mentioned that several V2 experimenters had tentatively interpreted some of their Saturn encounter observations in the context of a tail encounter. It is therefore of importance to examine the start and stop times of the encounter episode to determine if tail immersion and emersion times can be assigned. The first unambiguous signature of the onset of the SKR dropout occurred at 10 h spacecraft event time (SCET) on day 238. This is exactly one day after the first indication in the magnetic field data of a sunward reorientation of the field topology (10 h, day 237). This 24-hr time delay between the first possible indication of a tail immersion and the subsequent SKR response is consistent with the one-day delay observed in both the individual (Figure 2) and averaged event (Figure 5) cases. Thus the start time of the encounter dropout is consistent with the first immersion into the wake region at ~10 h, day 237.

The beginning of the SKR dropout may have occurred even earlier than this; however, viewing geometry problems have complicated the interpretation of the data. As reported by Kaiser and Desch [1982], both the northern and southern hemisphere radio sources were briefly 'occulted' when the spacecraft moved into null regions of the source beaming patterns. This occurred from about 0300 to 0530 SCET on day 238, or a few hours following closest approach to Saturn. In addition, for several hours before and after the occultation, the beaming geometry of both sources was such that only a small fraction of their total emitted power was able to reach the spacecraft. Although the SKR dropout may have begun as early as 14 h on day 237, the complicated source viewing geometry during the encounter makes onset identification difficult.

The SKR dropout ends near 0 h on day 242, so that the total duration of the V2-Saturn encounter episode is at least 86 h, or 8 Saturn rotations. Since we know that the SKR always recovers to normal energy levels well before the end of any tail encounter, it seems likely that Saturn was immersed in Jupiter's tail and wake region through day 242, at least until the last reported bow shock encounter at 0108 h on day 243.

The 'core' of the SKR dropout, when the minimum radio energy was detected, extended from day 239, 0200 h to day 240, 1400 h. This is probably within a day or two of the center time of the immersion in Jupiter's tail. This interval also overlaps the time (day 240, 0205 h) of the strongest nonthermal continuum event identified by Kurth et al. [1982b] as possible Jovian continuum emission. The coincidence of its occurrence during the SKR dropout minimum lends credence to its identification as Jovian continuum. Although the superposed epoch results of Figure 5 showed a 2-4 day delay between the core of the SKR dropout and the core of the tail immersion, these are average delays derived from several tail encounters. The detection of the possible Jovian continuum emission only one day after the start of the SKR core dropout suggests that, for the V2 encounter event, this delay is somewhat shorter than the average obtained from the superposed epoch analysis of Figure 5.

Kurth et al. also detected an earlier but weaker continuum event at 0845 SCET on day 236 at about 35 R_s (R_s=Saturn radius) upstream of Saturn's bow shock. Less than 4 hr earlier, a short-lived, one-rotation diminution in the SKR occurred. This was not a major SKR dropout of the type shown in Figures 2 and 3, but it was the largest decrease by a factor of five that occurred in the 10 days prior to the encounter dropout. Kurth et al. suggested that this continuum event marked the detection of a Jovian wake encounter by Voyager 2. The simultaneous observation of a strong minimum in the SKR output helps identify this event as a precursor to the major tail immersion that occurred during V2 encounter with Saturn two days later.

Summary and Conclusions

We have shown that Saturn experienced repeated and sometimes sustained encounters with the magnetic tail of Jupiter during the period from May through August, 1981. This conclusion is based on Voyager 2 observations of strong decreases in the energy level of the Saturn radio emission which are closely associated with times when the spacecraft was also inside Jupiter's magnetic tail. Voyager 1 observations over a similar length of time and inbound trajectory showed no such radio emission dropouts. The restriction of the dropouts to the V2 analysis interval is explained by the proximity of Saturn at this time to the Jupiter-sun line, and hence to Jupiter's extended tail.

The radio emission dropouts themselves are largely explained by the fact that the solar wind pressure, which is the principal driver of the SKR can drop below average low solar wind conditions by several orders of magnitude during a tail immersion. Not presently understood, however, is the consistently observed, premature recovery of the SKR to normal energy levels. While Desch and Rucker [1983] showed that the solar wind ram pressure is an excellent predictor of SKR output under normal solar wind conditions, the tail-related dropouts present a more complicated situation that has not been fully analyzed as yet.

The last magnetotail immersion reported in this paper occurred during the Voyager 2 encounter with Saturn while the spacecraft was inside Saturn's magnetosphere. From start to finish, this tail encounter lasted at least 86 hours. The timing of the SKR dropout observed during the encounter is consistent with the following sequence of events:

1. A brief, precursor wake encounter took place from about 4 hr to 9 hr SCET on day 236 when the SKR declined below normal levels and Kurth et al. [1982b] observed nonthermal continuum.

2. The initial encounter of Saturn's magnetosphere with Jupiter's tail proper probably took place at about 10 hr SCET on day 237 when Saturn's field lines rotated sunward [Ness et al., 1982] and a major increase in energetic charged particle fluxes occurred [Vogt et al., 1982]. Within 24 hr of this initial immersion, the SKR

energy began to diminish rapidly.

3. The deepest part of the tail encounter was probably near day 240. During this day the SKR energy reached its lowest point, and strong Jovian-like continuum emission was observed by Kurth et al. [1982b]. Voyager was 36 to 47 R_s from Saturn and still within Saturn's magnetosphere during the first 2/3 of day 240.

4. Saturn's magnetosphere remained under the influence of the Jovian tail at least through day 242. The SKR dropout ended at the beginning of this day and Saturn's outer magnetosphere was observed by Ness et al. [1982] and by Bridge et al. [1982] to be vastly inflated relative to Voyager 1 observations.

Saturn is possibly the only planet in the solar system whose magnetospheric dynamics is controlled, over certain intervals of time, by the extended magnetotail of another planet. For at least 6 months to perhaps a year, every 19.9 years, Saturn is repeatedly engulfed by Jupiter's tail. During this 6-month to 1-year period it spends about 10 to 20% of the time under Jupiter's influence. The directly observed effects in Saturn's outer magnetosphere, judging from the V2 encounter observations, include greatly enhanced energetic particle fluxes and an overall inflation and reorientation of the magnetic field. The effects must also extend to much lower altitudes, even to cloud top levels, (but perhaps only at high latitudes) since the SKR radio source is located here and its output is drastically reduced.

Although we know that Saturn can be engulfed by Jupiter's tail, the possibility exists that Uranus is similarly influenced if the Jovian magnetotail is indeed 15 AU long as modeled by Grzedzielski et al. [1981]. Additionally, Saturn's magnetotail would have to be about 10 AU long to engulf Uranus, which is not likely, however. The opportunity for Voyager 2 to observe an immersion of Uranus into Jupiter's tail could come only in late 1983 or early 1984 when Uranus is less than about 12° from the Jupiter-sun line. This assumes, of course, that low-frequency Uranus radio emission exists, is driven by the solar wind, and can be detected this early by the Voyager PRA experiment. The optimum geometry to view an immersion into Saturn's tail would come later. Voyager will be in a position to observe possible dropouts in the Uranus radio emission between February and August 1986 when Uranus is less than about 15° from the nominal Saturn–sun line.

Further analysis of the Saturn data in light of our present understanding of the V2 encounter interval may prove useful in the investigation of magnetospheres under highly anomalous conditions.

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Figure Captions

Fig. 1. Three total power dynamic spectra showing strong SKR activity on day 179 (panel a), very weak activity on days 181 and first 17 h of day 184 (panels b followed by c), followed by the reappearance of strong SKR at 1700 hours spacecraft time on day 184 (panel c).

Fig. 2. Emitted SKR energy per rotation (joules/rotation, J/rot) is compared with the occurrence of a PLS low density event. The low density event is coded such that unshaded, hashed, and shaded areas indicate upper limit plasma densities at Voyager 2 of 0.05, 0.03, and 0.01 cm–3, respectively. Timing of PLS event is from Kurth et al. [1982a]. It corresponds to event number 23 of Kurth et al. and to number 6 of Lepping et al. [1983].

Fig. 3. Voyager 2 survey plot of SKR energy per rotation (J/rot) showing the occurrence of SKR dropouts (shaded intervals). Each dropout indicates the immersion of Saturn into Jupiter's magnetotail.

Fig. 4. Same as Figure 3 but for Voyager 1 data. No SKR dropouts occurred during this time interval.

Fig. 5. Superposed epoch analysis of SKR dropouts (excluding last episode) shown in Fig.3. Figure shows close association between occurrence of low density plasma events as observed at Voyager 2 and disappearance of the Saturn kilometric radiation.

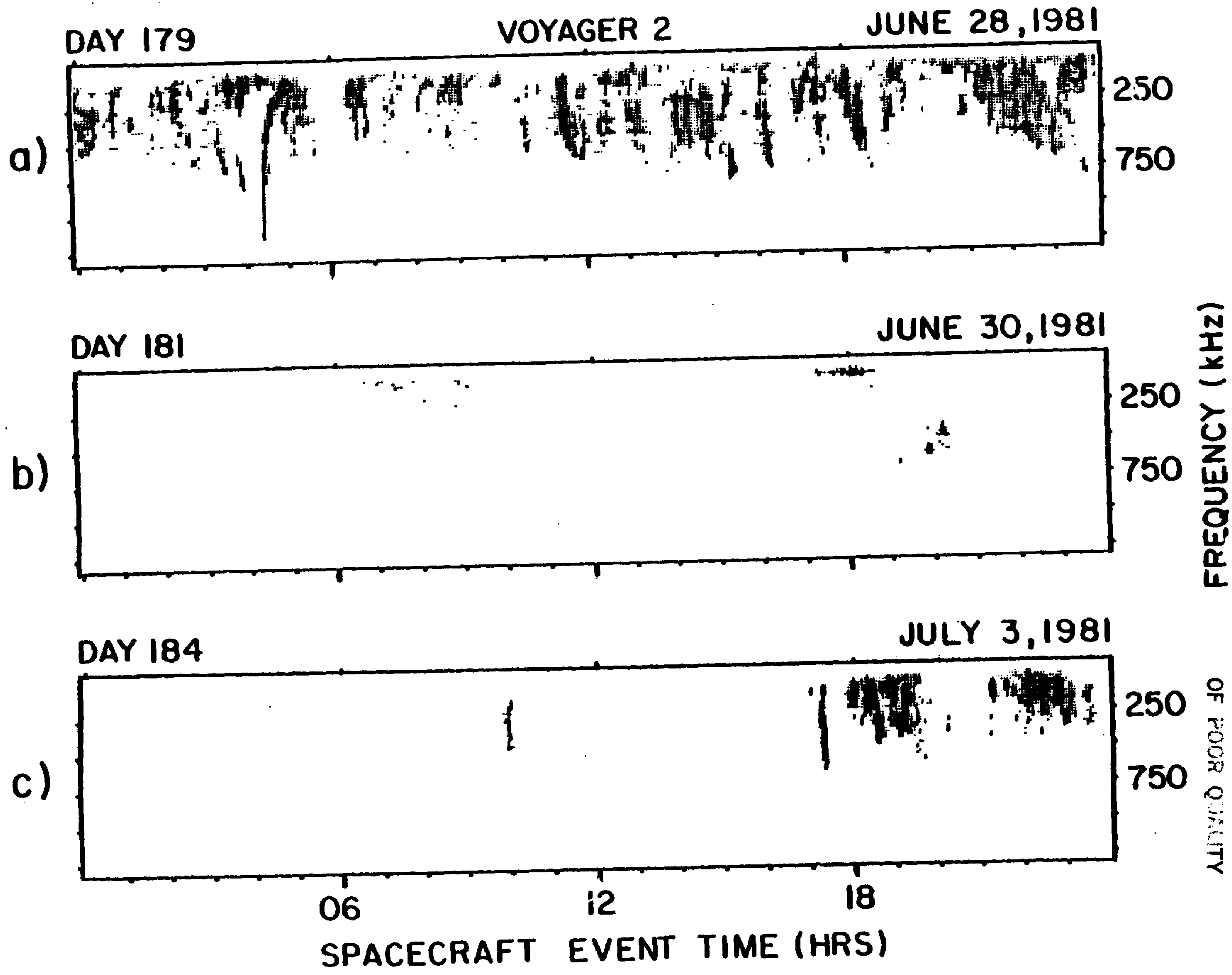
DAY 179
VOYAGER 2
JUNE 28,1981
a)
DAY 181
JUNE 30,1981
b)
DAY 184
JULY 3,1981
c)
250
750
FREQUENCY (kHz)
06
12
18
SPACECRAFT EVENT TIME (HRS)

FIGURE 1

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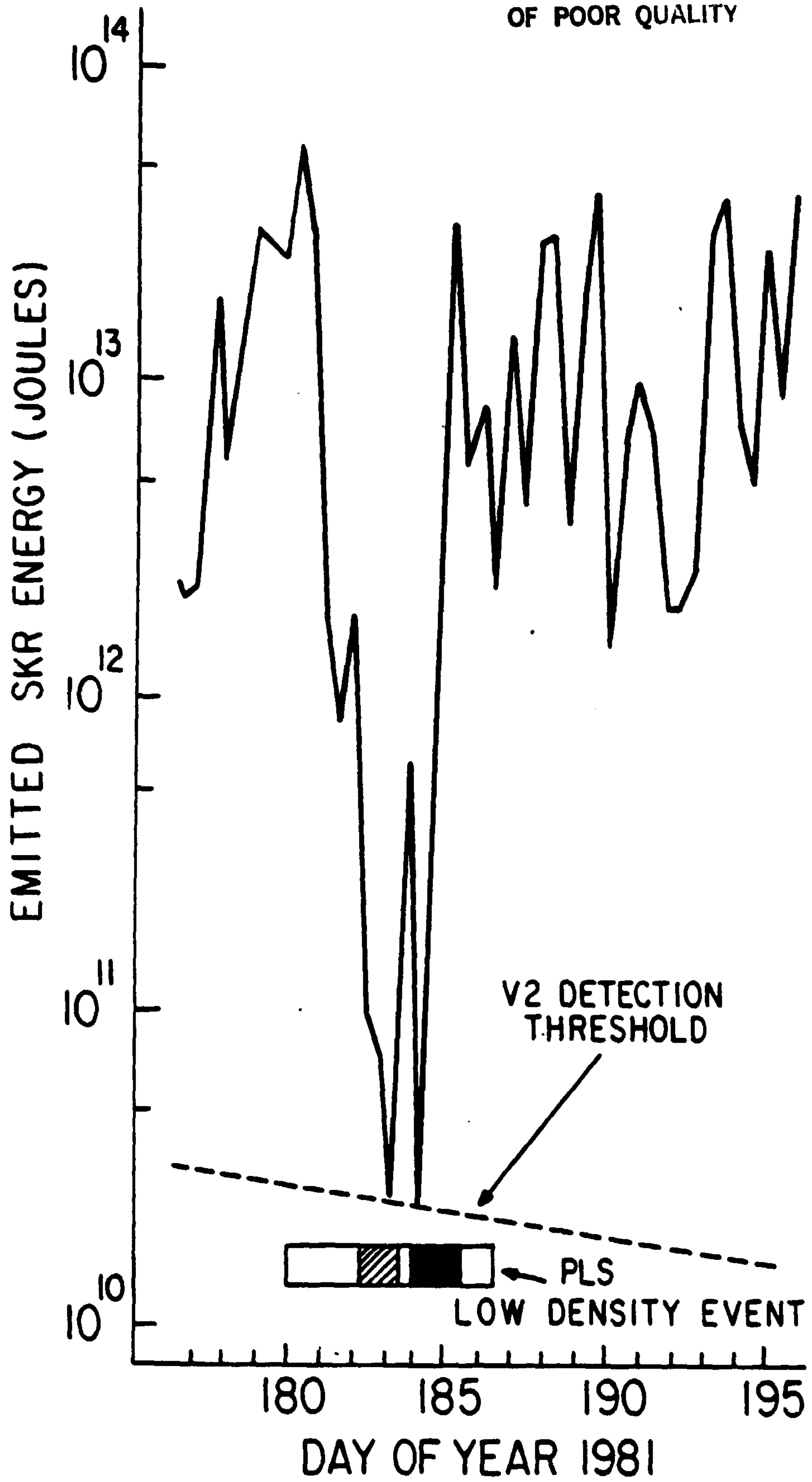
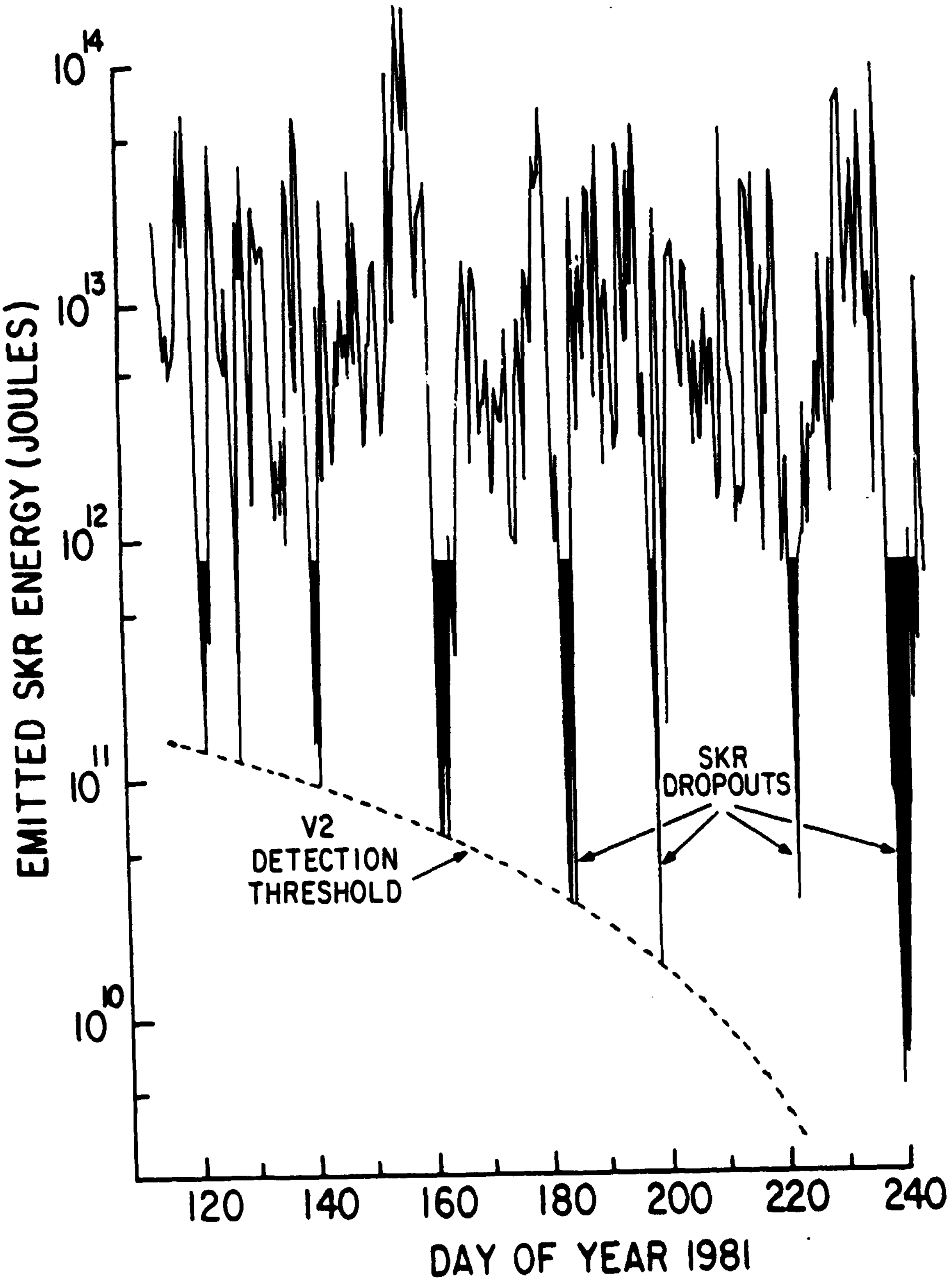


FIGURE 2


EMITTED SKR ENERGY (JOULES)
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120
140
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DAY OF YEAR 1981

FIGURE 3

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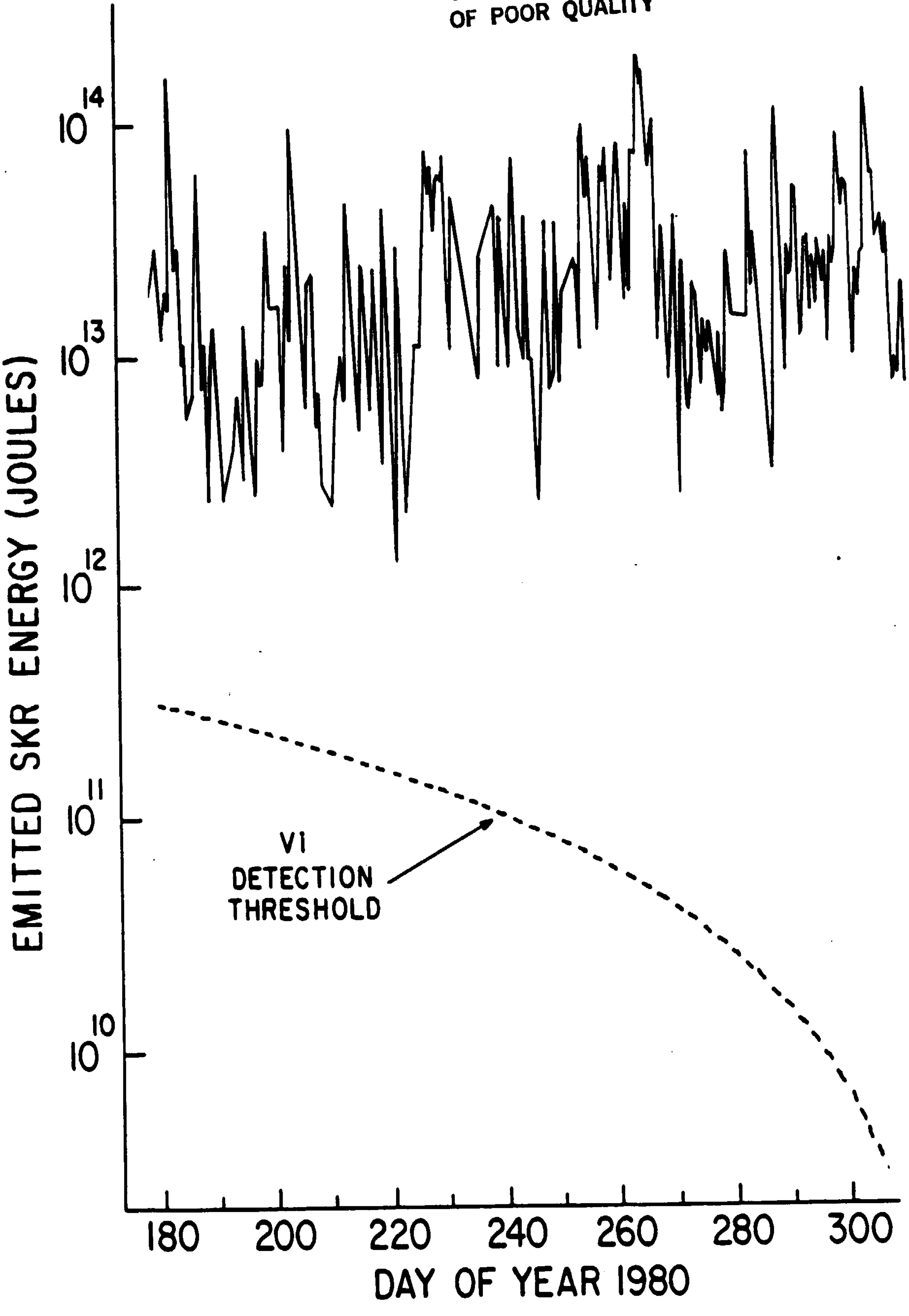

FIGURE 4

ORIGINAL PAGE IS
OF POOR QUALITY

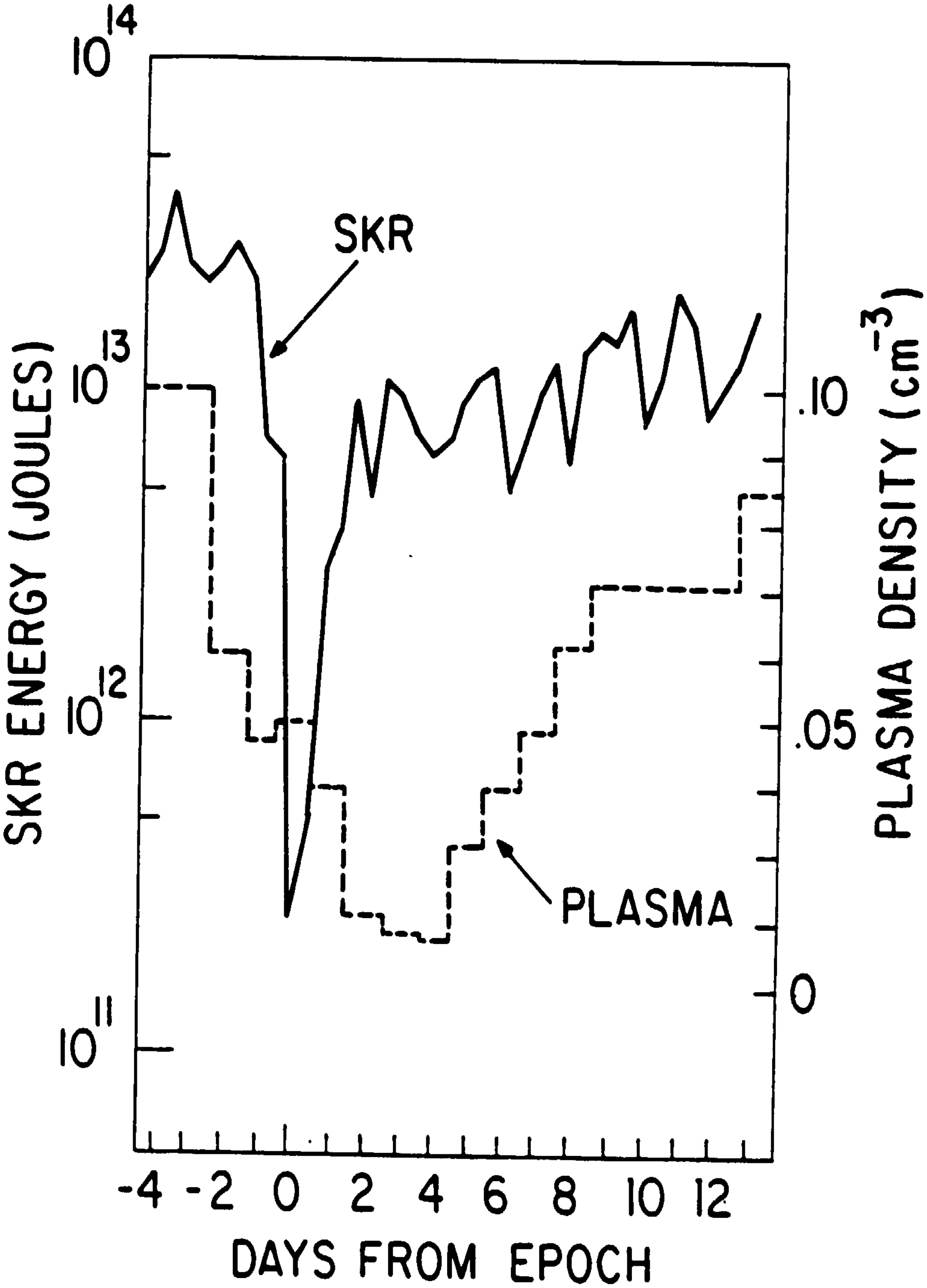

FIGURE 5