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A Report on Observations of Jovian Decametric Radiation during the SL9/Jupiter Impact Period

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Abstract

Many fragments of the Shoemaker-Levy 9 comet (SL9) collided with Jupiter from July 16 through July 22 in 1994. During the SL9/Jupiter impact period we monitored the Jovian decametric emission activity at Nishi-harima Astronomical Observatory, paying attention to each of the observable fragment impacts (fragments C, D, G, K, N, and W). To reliably identify Jovian radiation we made observations with a phase-switched interferometer having a baseline of 193 m, a polarimeter, and two radiometers. In addition, dynamic spectrum observations were also made using an array consisting of 4 conical log-spiral antennas. We identified no Jovian decametric emission that was definitely related to any of the fragment impacts, although Jupiter-like narrow band radiation was observed at about 22.2 MHz about 30 min prior to the impact of fragment G on July 18. We identified an Io-related B (Io-B) storm just after the impact of fragment C on July 17. The characteristics of this Io-B storm were not different from those of a normal Io-B storm. We conclude that the SL9 collision with Jupiter had no significant effect on the Jovian decametric emission activity.

Key words: Jupiter: Decametric emission: Comet collision

1. Introduction

We started a series of observations in January 1995 with a polarimeter, an interferometer, and two radiometers. The data were recorded on the pen recorder at a relatively low chart speed of 6 cm/h. During the SL9/Jupiter Impact period, we made extensive observations which are described in section 2. After the SL9/Jupiter impact period, we continued recording the data at 6 cm/h on the pen recorder. Io-related storms were often identified before and after the SL9/Jupiter impact period. No significant emission activity change was detected before and after the SL9/Jupiter impact period. In this paper we will report three emission events that were observed in the SL9/Jupiter impact period.

2. Observations

Our observations during the SL9/Jupiter impact period are summarized in Table 1. Interferometer and polarimeter outputs were recorded on a pen recorder at a chart speed of 30 cm/h and on a digital recorder at a sampling rate of 5 Hz. The outputs of two radiometers were also recorded on the pen recorder and on another digital recorder at a sampling rate of 5 Hz. Furthermore, the AF (audio frequency) outputs of the radiometer receivers were recorded on a digital audio tape recorder. Dynamic spectrum observations were made in a frequency range 16-36 MHz, using a commercial spectrum analyzer. The instantaneous band width of the spectrum analyzer was 30 kHz and the frequency scan was made every 1 sec. The scan data of the spectrum analyzer were digitized with an analog-digital converter controlled by a personal computer and recorded on a hard disk. We also watched the dynamic spectrum displayed on a CRT monitor during

Table 1. Observations of Jovian Decametric Radiation at NHAO in the SL9/Jupiter Impact Period

Dynamic Spectrum	
antenna	RH conical log-spiral (× 4)
frequency range	16-36 MHz
scan rate	1 Hz
instantaneous bandwidth	30 kHz
Interferometer	
antenna	3 element Yagi (× 2)
baseline	193 m
frequency	21.86-22.20 MHz
bandwidth	10 kHz
Polarimeter (RH-LH)	
antenna	crossed 3 element Yagis
frequency	21.86-22.20 MHz
bandwidth	10 kHz
Two Radiometers	
antenna	RH conical log-spiral (× 4)
frequency	two frequencies (20-25 MHz)
bandwidth	10 kHz

manned observation periods. The minimum detectable flux density was dependent on observing conditions (e.g., degree of interference), but was nominally $5 \times 10^{-22} - -10^{-21} Wm^{-2}Hz^{-1}$.

Nominal observation time at NHAO was 0600-1200 UT (1500-2100 JST) for each day. It is well known that the occurrence probability of Jovian decametric radiation within a narrow frequency range is a joint function of the central meridian longitude (CML) in System III and the orbital phase of Io (e.g., Carr et al., 1983). In Figure 1 the observation track in the CML-Io phase plane for each day in the SL9/Jupiter impact period is indicated by a line segment on an occurrence probability plot made by Thieman(1988, private communication). Each of the impact times of the observable fragments (C, D, G, K, N, and W) is indicated by an arrow in Figure 1.

The observing frequencies of the interferometer, the polarimeter, and the two radiometers were often changed to avoid man-made interference. The aural monitoring of the AF signals of the radiometer receivers were useful to detect the man-made interference signals and atmospherics. Typical observing frequencies of the polarimeter and the interferometer were 21.87, 21.9, 22.0, and 22.2 MHz. Those of the radiometers were 23.3, 24.4, 25.0, 25.3, 25.5 MHz.

Terrestrial lightning emissions were frequently observed in the afternoon and in the evening. The critical frequency of the terrestrial ionosphere strongly affects the observing condition. As the critical frequency of the ionospheric F layer becomes greater, the frequency range in which the interference signals appear extends toward higher frequencies on the dynamic spectrum. In the SL9/Jupiter impact period the critical frequency of the F layer often had a maximum around 1000-1100 UT (1900-2000 JST), near the transit time of Jupiter. Furthermore, interference signals were sporadically intensified presumably due to the occurrence of a sporadic E layer. On such an occasion, new interference signals appeared and pre-existing interference signals were intensified. In order to show what the typical observing condition in a frequency range 16-36 MHz was like in Japan in the SL9/Jupiter impact period, the dynamic spectrum of July 21 is displayed in Appendix.

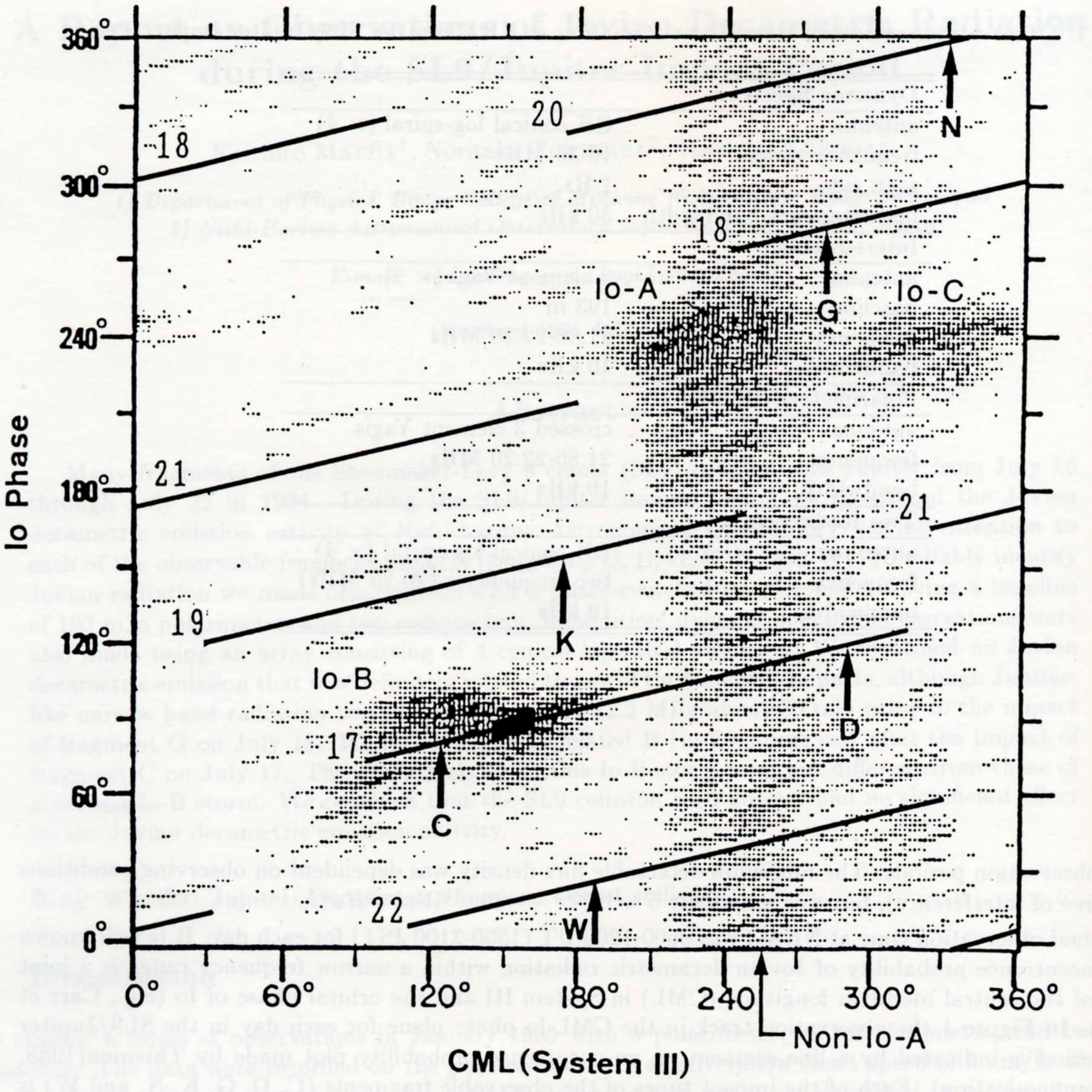

Fig. 1. Observation Tracks in the CML vs. Io-phase plane. The observation track for each day is represented by a line segment in an occurrence probability plot at 22.2 MHz made by Thieman. Each of the fragment impact times is indicated by an arrow labeled with the corresponding fragment name. The Jovian Io-B storm identified on July 17, 1994 is indicated by a thick line segment.

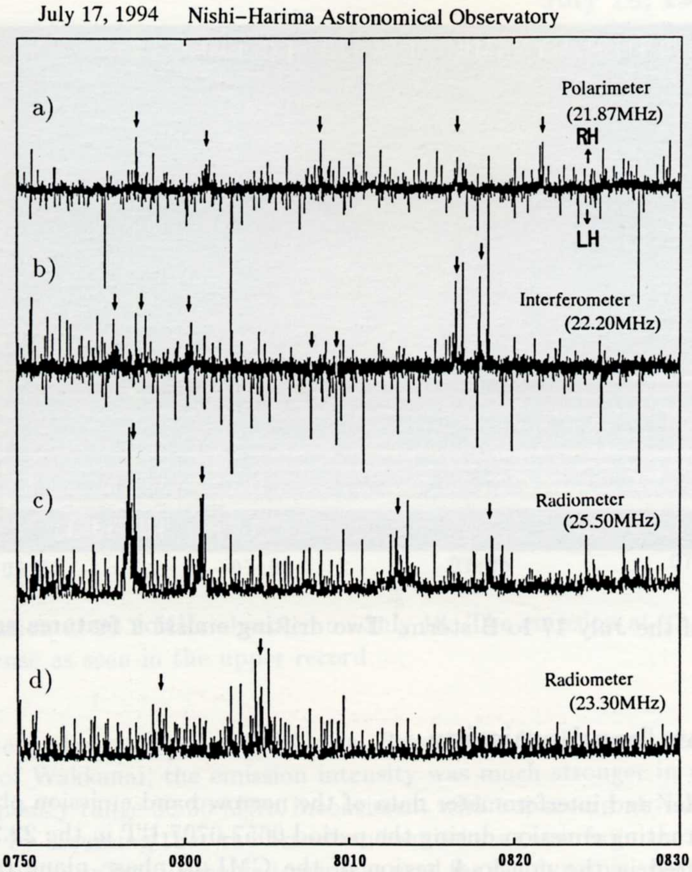

Fig. 2. Io-B storm observed on July 17, 1994. a) record of the polarimeter, b) interferometer record, c) radiometer record at 25.5 MHz, and d) radiometer record at 21.87 MHz. Several Jovian bursts are indicated by the arrows.

3. Jovian Io-B Storm

We identified a Jovian decametric storm during 0750-0840 UT on July 17. This is the only Jovian storm that we unambiguously identified in the SL9/Jupiter impact period. This storm occurred in the Io-B region of the CML-Io phase plane as shown by the thick solid line segment in Figure 1, and just after the impact time of fragment C.

The polarimeter and interferometer records of this Io-B storm are shown in Figure 2. The radio bursts were all polarized in the right-hand circular sense (Figure 2a), and the sign of the interferometer output (Figure 2b) changed consistently with the interferometer fringe pattern of Jupiter. We heard S-bursts sounds by the aural monitoring. The dynamic spectrum of this storm is shown in Figure 3. Two arc-like drifting structures were seen in the dynamic spectrum. The arc-like structures were also detected by the dynamic spectrum observations at Culgoora Observatory, Australia (Prestage, 1995), and also at Wakkanai Branch, Radio Research Laboratory, Japan (Tokumaru, 1994). The characteristics of the July 17 Io-B storm are not different from those of a normal Io-B storm. We found no particular effect of the impact of fragment C on this Io-B storm.

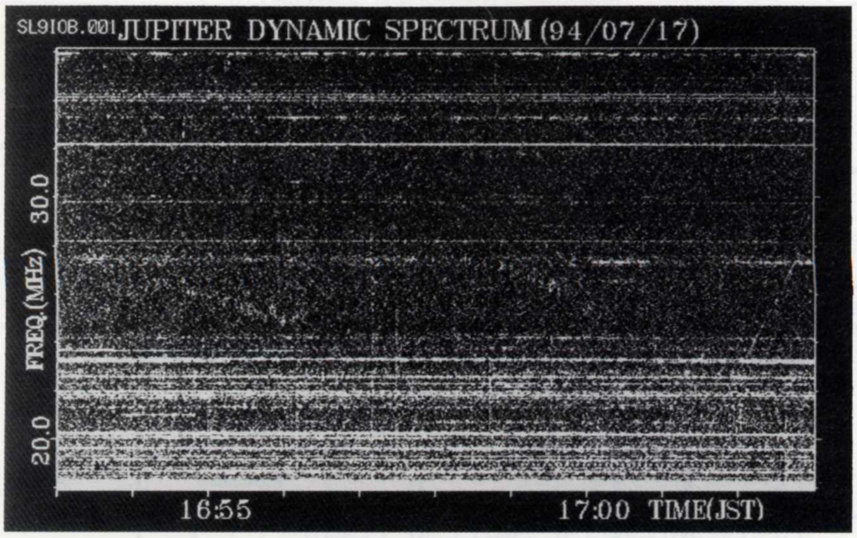

Fig. 3. Dynamic spectrum of the July 17 Io-B storm. Two drifting emission features are indicated by the arrows.

4. Jupiter-like narrow band emission

Figure 4 shows the polarimeter and interferometer data of the narrow band emission observed on July 18. We can see the intensity-fluctuating emission during the period 0657-0707 UT in the 22.2 MHz polarimeter record. This emission occurred in the non-Io-A region of the CML-Io phase plane (see Figure 1), and about 30 min prior to the impact time of fragment G. The radiation was polarized in the left-hand circular sense, differing from the normal non-Io-A emission. The radiation was also received with the interferometer at 21.87 MHz. The time variation of the emission intensity in the interferometer record was significantly different from that in the polarimeter record, presumably due to the difference in observing frequency.

On July 18, 1994, we received an e-mail saying that the Comet-Impact Team of Beijing Astronomical Observatory reported a strong Jovian radio storm at 25 MHz just during the same period in which we observed the Jupiter-like radiation at 22.2 MHz. Since we thought that the emission might be broadband, we submitted an e-mail report saying that we also received Jovian radiation at NHAO. However, a later detailed analysis of our dynamic spectrum revealed that no radiation was observed at 25 MHz, and that the radiation was narrow band one at about 22.2 MHz. It seemed that the sign of the interferometer output DC voltage at 21.87 MHz was not inconsistent with that of the radiation from Jupiter. It is uncertain that the same narrow band emission was received at observatories located in the southern hemisphere. We need some further evidence before concluding that this narrow band emission came from Jupiter. If the radiation were really from Jupiter, it might be related to the crossing of fragment G across the field lines that were connected with the southern Jovian aurora.

5. Solar Radio Bursts on July 18

Broadband emissions were observed during the period 0806-0809 UT on July 18, about 30 min after the impact time of fragment G. Analyzing the dynamic spectrum data, together with the published data of solar radio bursts, we conclude that these broadband emissions were solar radio bursts.

Three nearly-vertical emission streaks were observed in the frequency range 30-36 MHz on our dynamic spectrum as seen in Figure 5. It seemed that the emission frequency extended over 36 MHz. Such an emission pattern in the dynamic spectrum reminded us of solar bursts rather than Jovian bursts. The broadband

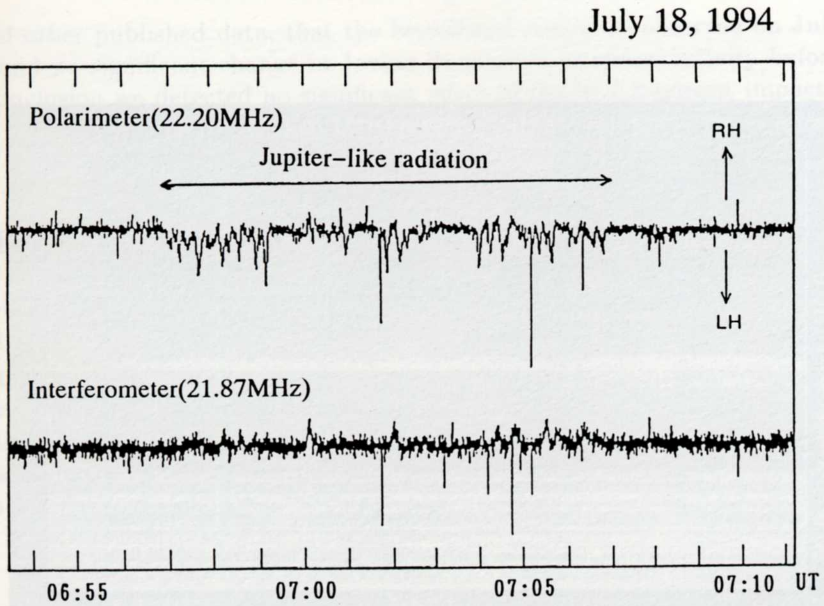

Fig. 4. Jupiter-like emission at 22.2 MHz observed on July 18. The emission at 22.2 MHz was polarized in the left-hand circular sense as seen in the upper record.

emissions on July 18 were also observed at Wakkanai Branch, Radio Research Laboratory. However, in the dynamic spectrum of Wakkanai, the emission intensity was much stronger in a frequency range 20-30 MHz than that in a frequency range 30-36 MHz, inconsistent with our record at NHAO. As we will mention below, this is explained by assuming that the broadband emissions came from the direction of the sun. At Wakkanai a log-periodic antenna installed on a tower was used for the dynamic spectrum observations, while a rectangular array (2 by 2) consisting of 4 conical log-spiral antennas was used at NHAO. Since the sun was west at a low elevation angle (about 23 deg.), for the radiation from the direction of the sun the lower part of the east-side element antenna in each east-west row of the array was blocked by the west side element antenna in the same row. Furthermore, the lower part of the west-side element antenna in the northern east-west row was also blocked by the crossed Yagis for the polarization observation. The lower-frequency emission is received at the lower part of the conical spiral antenna. Considering the geometrical relation among the antennas and the direction of the sun (see Figure 6), we conclude that for the radiation from the direction of the sun the receiving efficiency of the conical spiral array seriously dropped at frequencies below 30 MHz. This explains the reason why we did not receive appreciable emission below 30 MHz at NHAO.

The broadband emissions on July 18 were not observed at Culgoora Observatory (Prestage, 1995). If we assume that the emissions came from the direction of the sun, this can be explained by the fact that it was around sunset time at Culgoora. Furthermore, according to the Solar Geophysical Data (Numbers 600, and 601, Part I, 1994), several solar radio observatories (Leamonth, San Vito, Potsdam, Izmiran) reported solar type III bursts during 0806-0810 UT. The Ulysses data indicate the occurrence of solar type III bursts around 0810 UT (Desch et al., 1995). It is therefore concluded that the broadband emissions observed during 0806-0809 UT on July 18 were solar radio bursts.

6. Conclusions

We have unambiguously identified one Jovian Io-B storm in the SL9/Jupiter impact period. This storm occurred just after the impact of fragment C, but we found no particular effect of the fragment impact on this storm. We observed the narrow band Jupiter-like emission at 22.2 MHz on July 18. But we have found no further independent evidence to ascribe this emission to Jupiter origin. It has been shown, on the

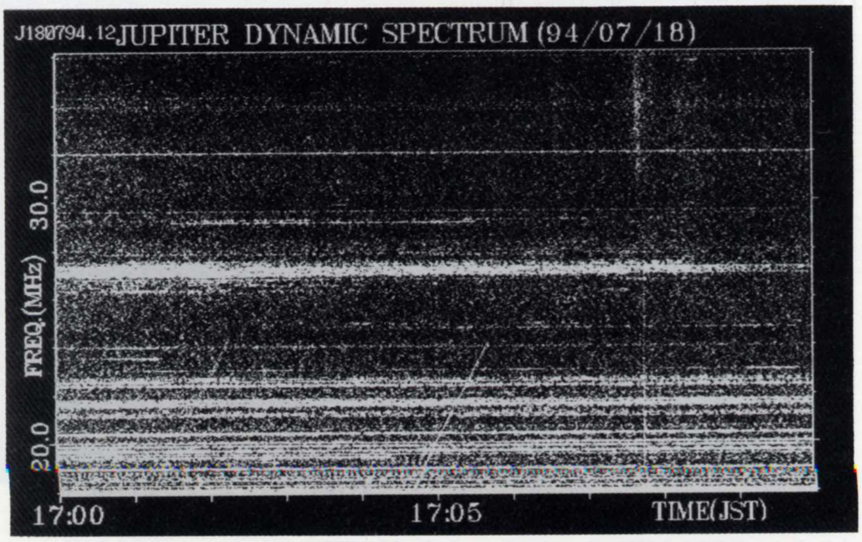

Fig. 5. Broadband emissions observed on July 18. It is concluded that these emissions were solar radio bursts (see text).

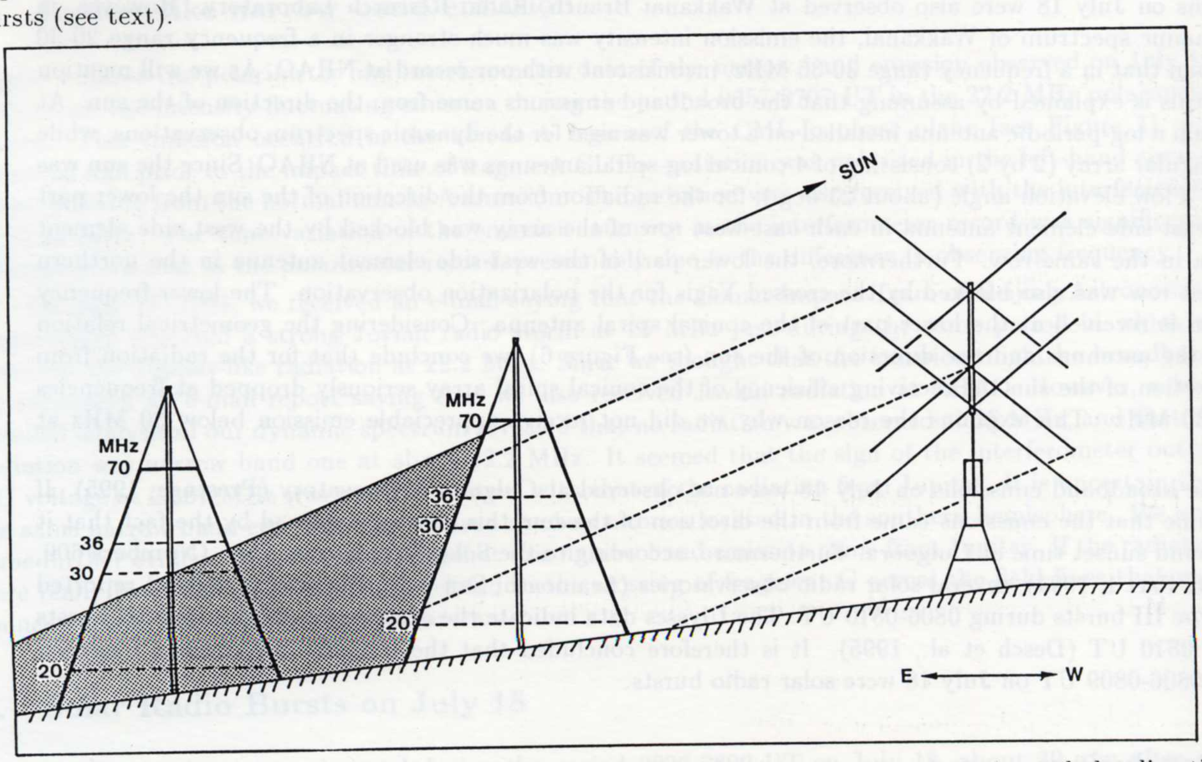

Fig. 6. Geometrical relation among two conical log-spiral antennas, the crossed Yagis, and the direction of the sun. Sensitive levels for the radiation at frequencies of 20, 30, 36, 70 MHz were indicated for each conical log-spiral antenna.

basis of our data and other published data, that the broadband emissions observed on July 18 were solar radio bursts. We found no significant change in Jovian decametric emission activity before and after the impact period. In conclusion we detected no significant effect of the SL9 fragment impacts on the Jovian decametric emission activity. This result is basically consistent with those of Carr et al. (1995) and an e-mail report by the French group (Zarka et al., 1994).

Appendix 1. Lightning Emissions

To show the observing conditions in Japan during the SL9/Jupiter impact period we demonstrate the dynamic spectrum data in the period 1500-2100 JST (0600-1200 UT) on July 21 (Figure A1).

Emissions due to terrestrial lightning appeared as thin vertical lines in the dynamic spectrum. The lightning emissions normally started in the early afternoon and continued through evening. For example, in Figure A1 several lightning emissions are seen in the period 1650-1700 JST (0750-0800 UT). If such broadband emissions could have originated in the Jovian atmosphere, the sign of the interferometer output DC voltage would have changed, following the fringe pattern of Jupiter. Since no such sign change was observed, they were simply terrestrial lightning emissions.

Appendix 2. Ionospheric Effects

In Figure A2 we plot the hourly average values of the critical frequency of the terrestrial ionosphere (foF2) measured at Kokubunji, about 500 km away from NHAO. As seen in Figure A2, the foF2 value was 5.1-5.7 MHz from 1200-1800 JST. then increased up to 8.1 MHz around 2000-2100 JST. It is noted in the data book that in the intervals 1300-1400, and 1800-1900 JST, the measurement was influenced by a lower layer, e.g., a sporadic layer. The foF2 value started increasing after 1800 UT on July 21 (Figure A2). As the foF2 value at Kokubunji increased, the interference signals became stronger and covered almost the whole frequency range in which our observations were made (see Figure A1).

Furthermore, we often experienced sporadic intensification of the interference signals presumably due to the occurrence of a sporadic E layer. A typical example of such a phenomenon is seen in the period 2000-2030 JST in Figure A1. We can see the intensification of the pre-existing interference signals, and sudden appearance of new interference signals. Even on such an occasion the interferometer record was useful to check whether the Jovian emission was received or not.

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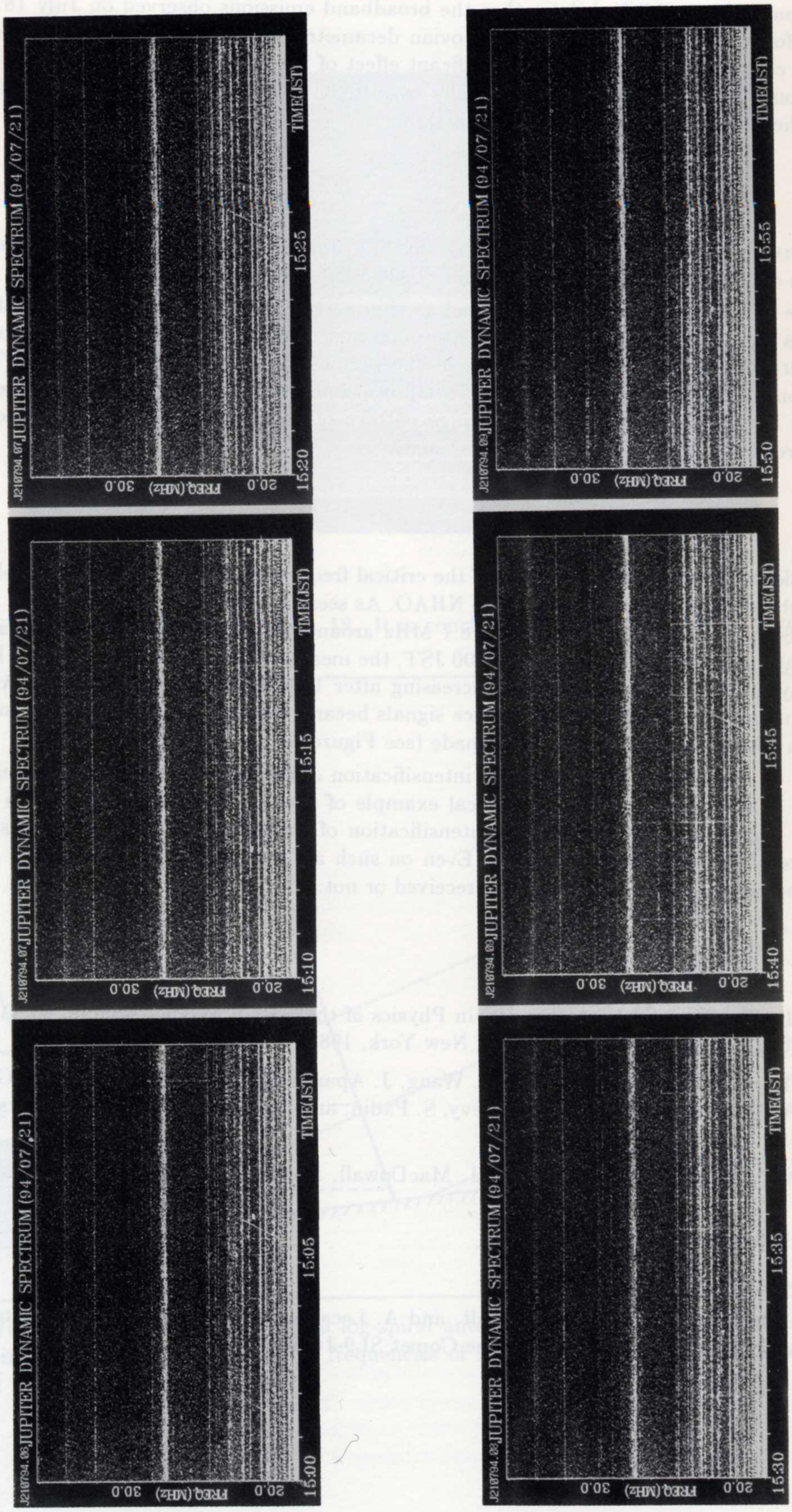


Fig. A1. Dynamic spectrum record in the period 1500–2100 JST on July 21, 1994. We can see lighting emissions and ionospheric effects on man-made interference signals. This dynamic spectrum displays a typical example of the observing condition that took place in Japan in the SL9/Jupiter impact period

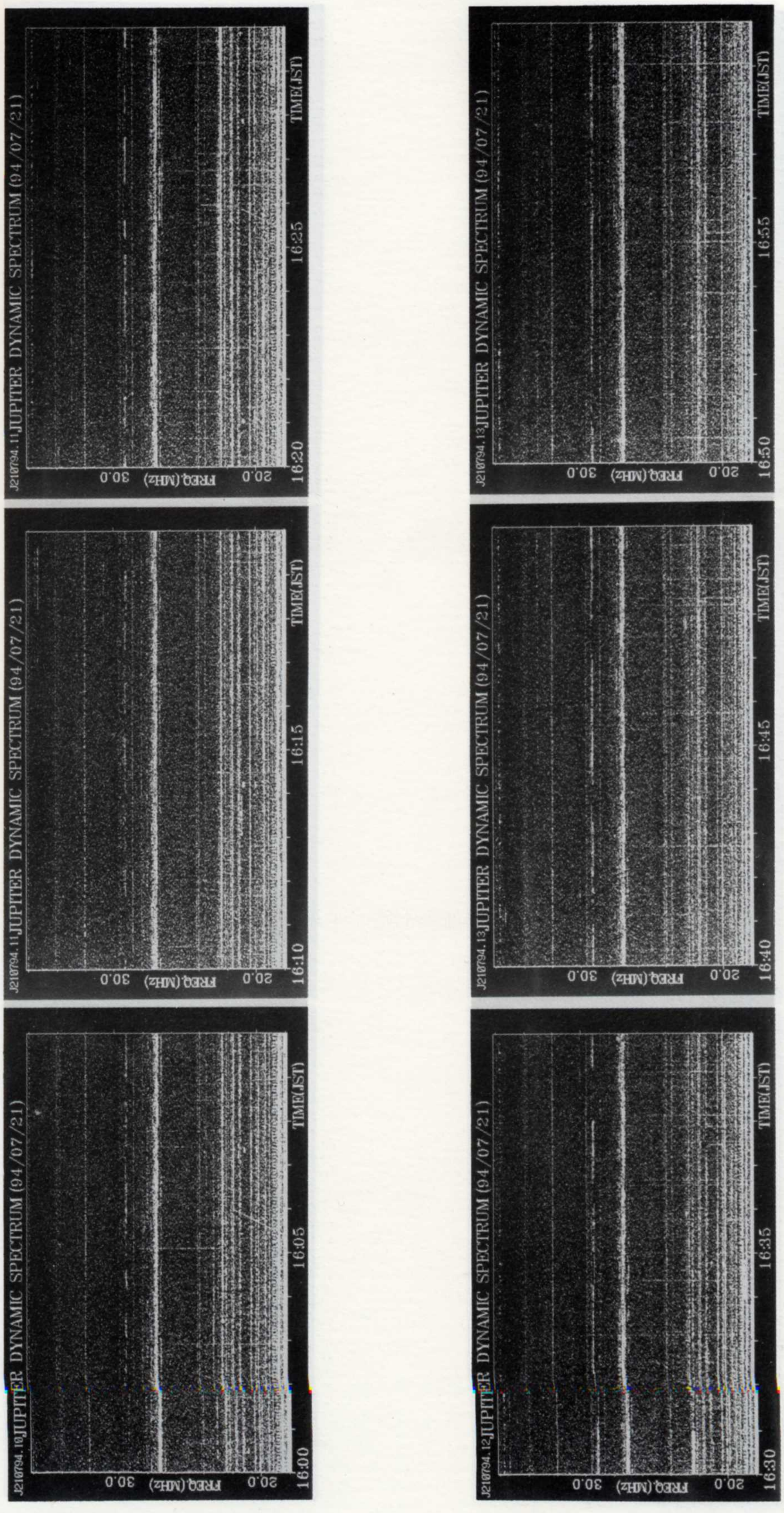
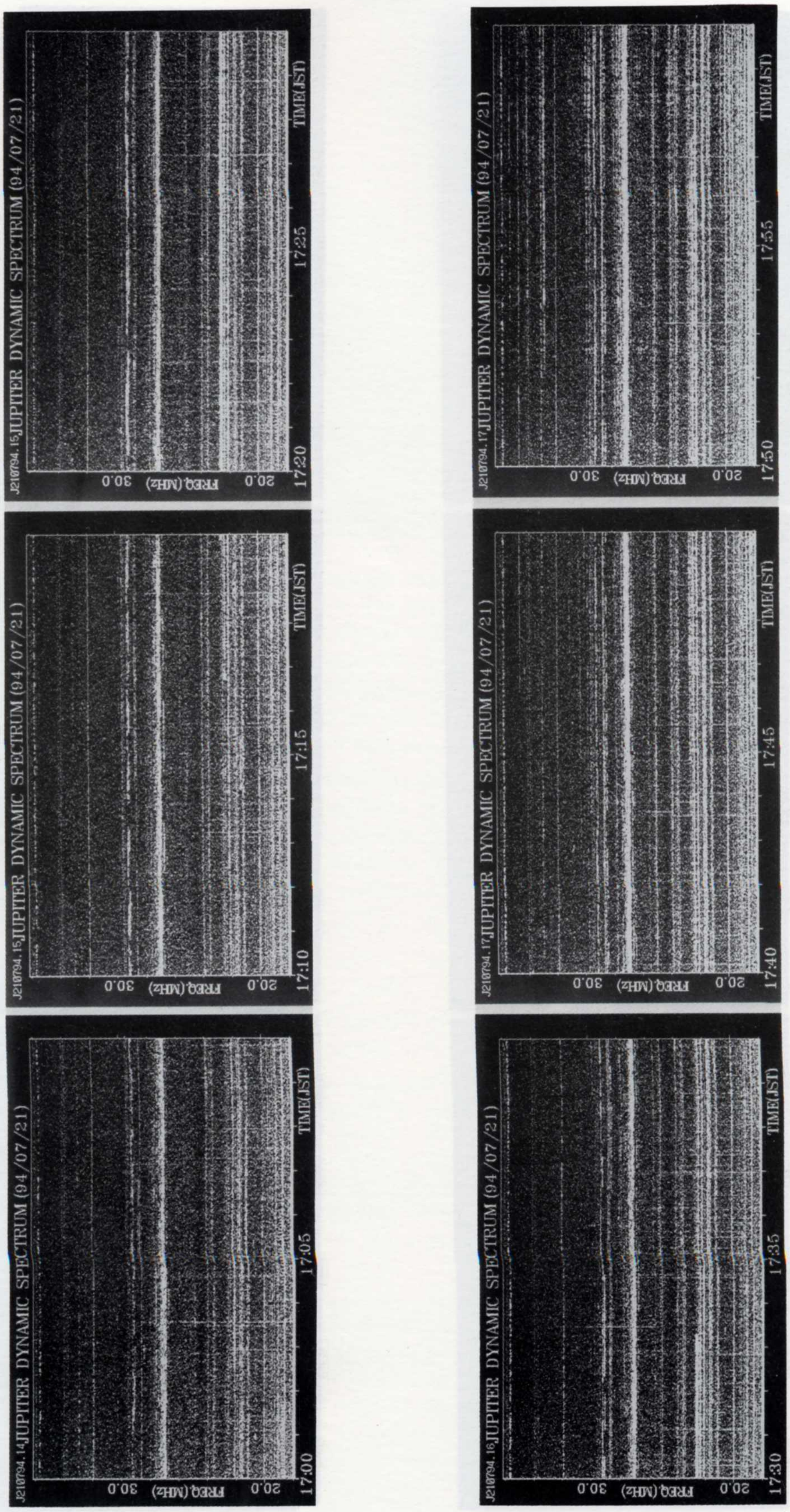


Fig. A1. (Continued)



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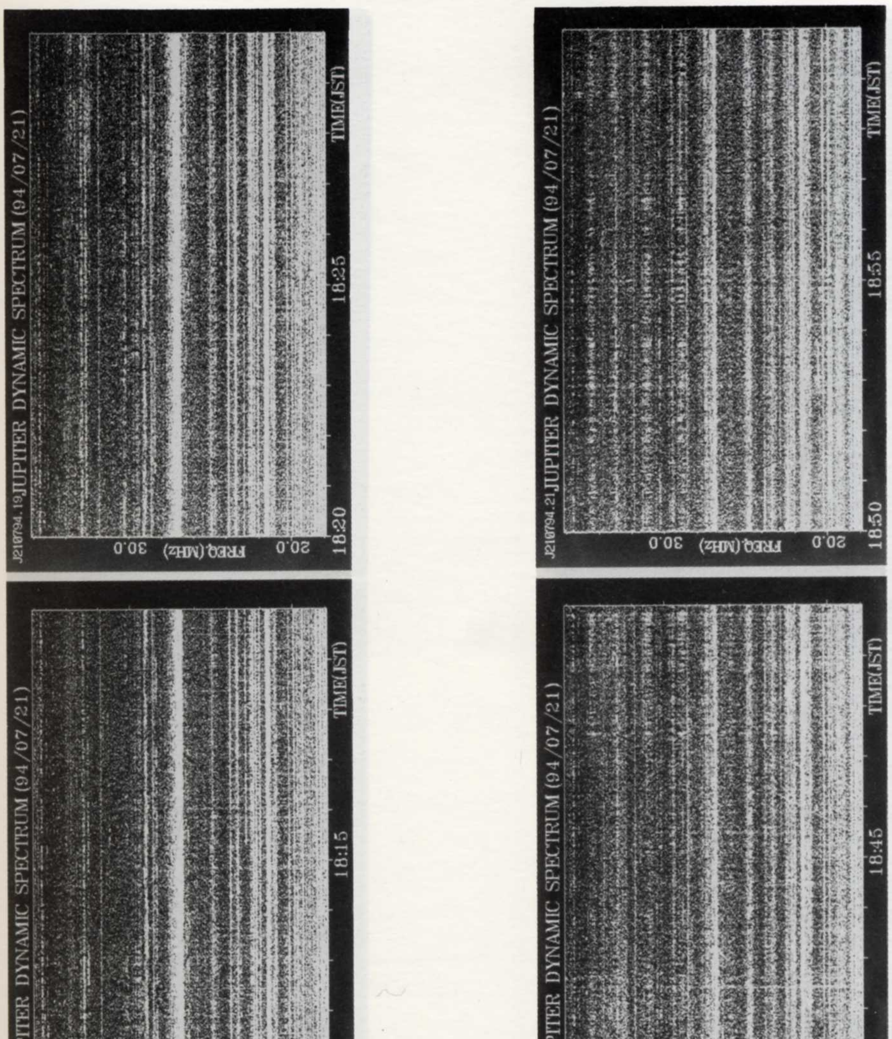

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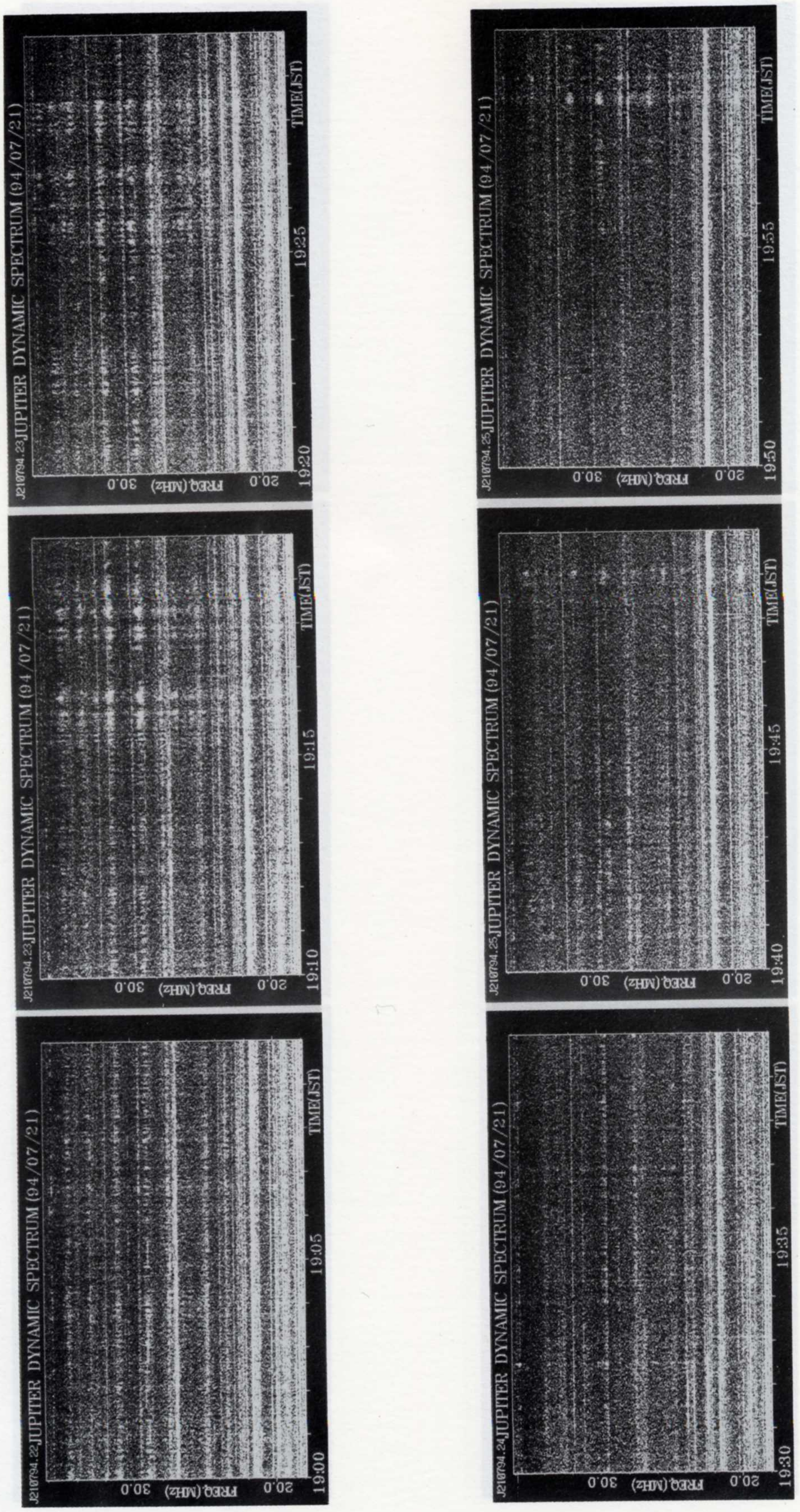

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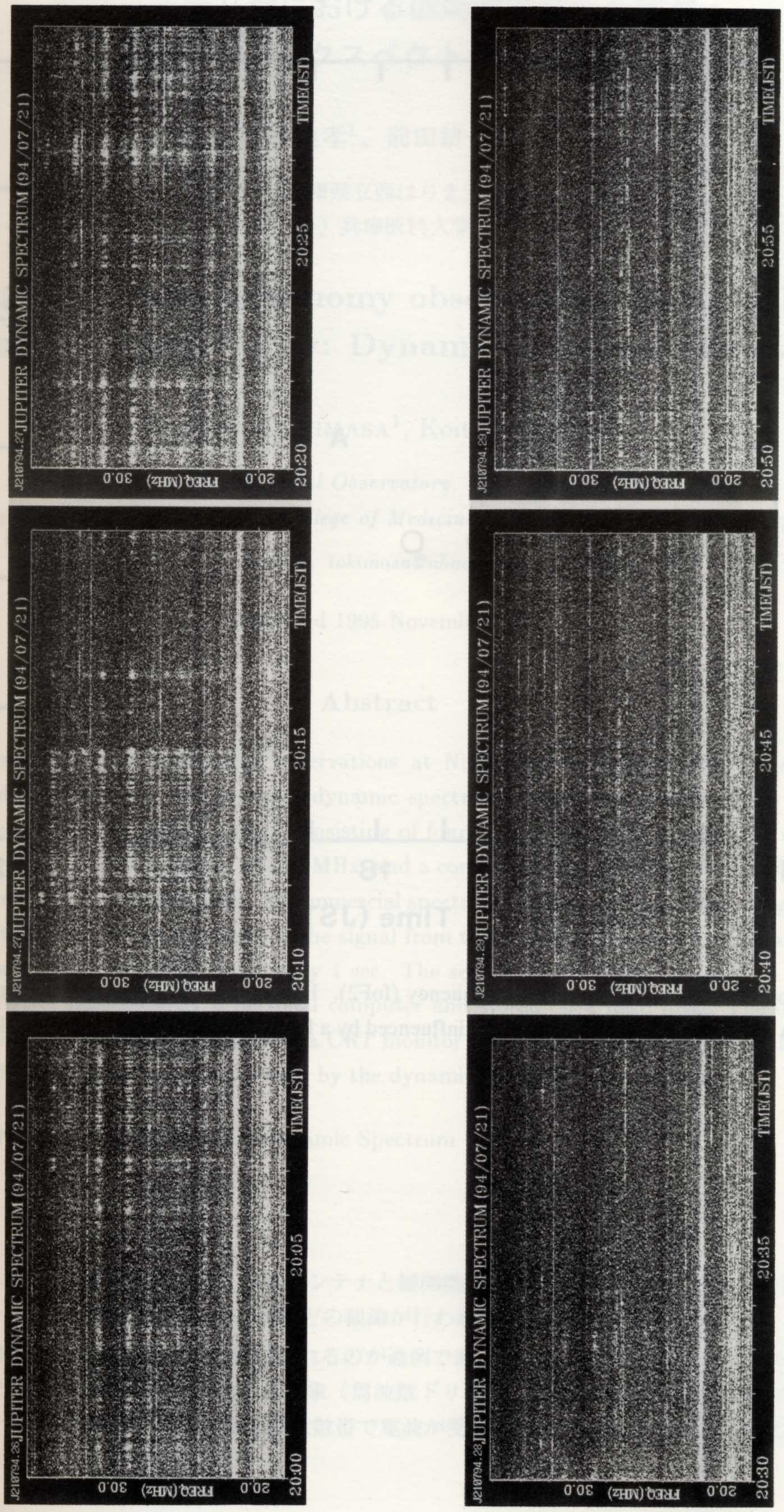

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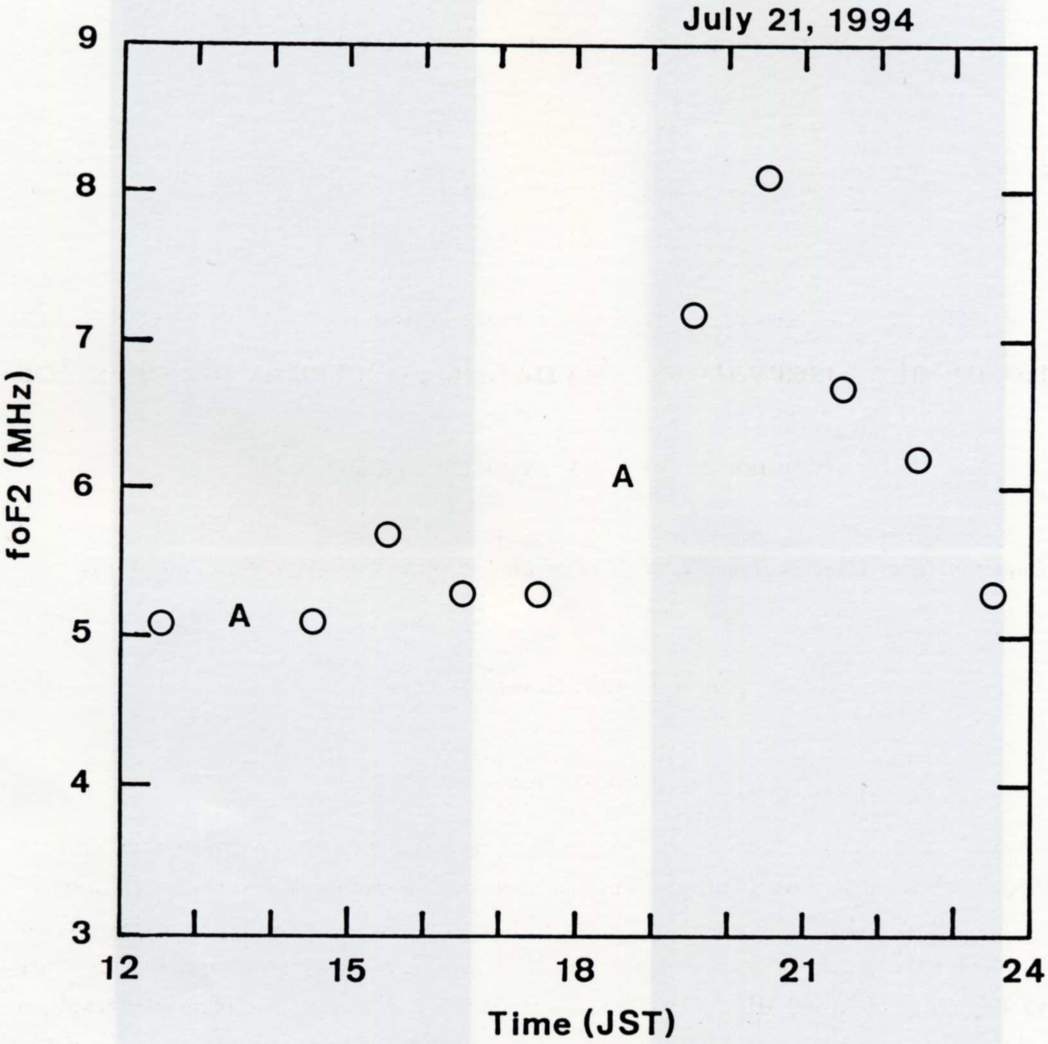

Fig. A2. Variation of the ionospheric critical frequency (foF2). Hourly average values mesured at Kokubunji are plotted. Letter A indicates that measurement was influenced by a lower layer such as a sporadic E layer.