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SOLAR MICROWAVE BURSTS ACCOMPANYING PROTON EVENTS.(U)

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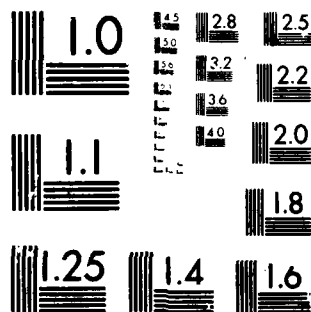
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SOLAR MICROWAVE BURSTS ACCOMPANYING PROTON EVENTS

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31 July 1979

Final Report for period 1 July 1977 - 30 June 1979

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Prepared for

AIR FORCE GEOPHYSICS LABORATORY
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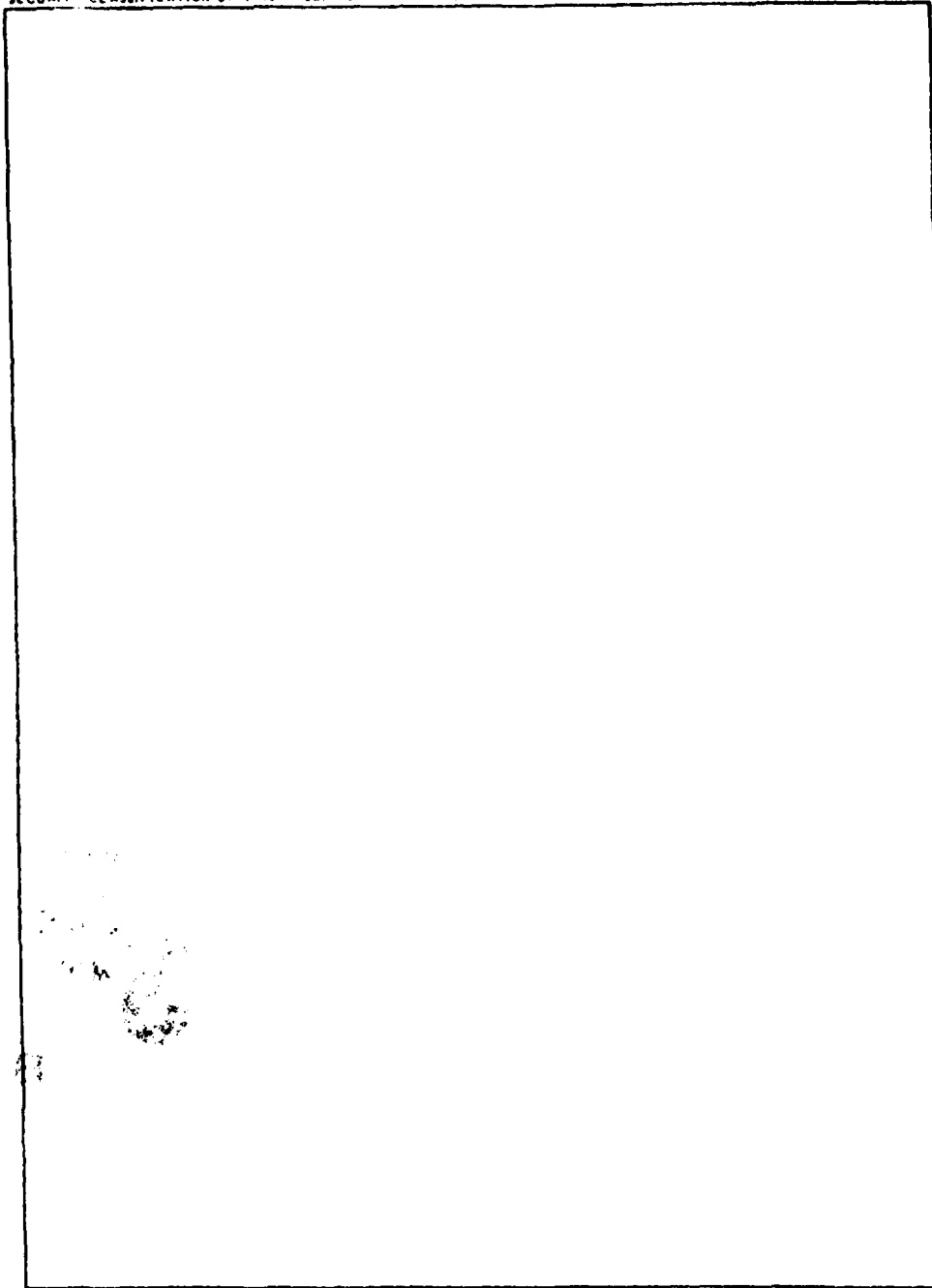
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A daily radio patrol was maintained at Manila Observatory. The cm sun was monitored at discrete frequencies: 8800, 4995, 2695, 1415 and 606 MHz, while the dekameter sun was monitored by a sweep frequency interferometer in the band 24-48 MHz. Microwave bursts accompanying six proton events are shown.			

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INTRODUCTION

This report describes the work performed in the period 1 July 1977 - 30 June 1979. A daily solar radio patrol over a wide frequency range, from cm to dekameter wavelengths, was maintained at Manila Observatory (14°38'N, 121°05'E) to complement the coverage at Sagamore Hill Radio Observatory (42°38'N, 70°49'W). The centimeter sun was monitored at five discrete frequencies: 8800, 4995, 2695, 1415 and 606 MHz. The dekameter sun was monitored by the Sweep Frequency Interferometer Radiometer in the 24-48 MHz band. A consolidated list and a set of data on punched cards containing both daily flux measurements of the quiet sun and distinctive events were sent each month to AFGL. Graphs of major radio bursts were sent to AFGL also. Centimeter and dekameter solar radio burst data were published in the monthly NOAA Solar-Geophysical Data.

DAILY FLUX VALUES: 1967-79

The solar radiometers for daily flux values employed the Dicke principle. Calibration of the radiometers was determined by intercomparison with corresponding daily flux values obtained at Sagamore Hill Radio Observatory. Observed flux values were adjusted to a sun-earth distance of one astronomical unit. Data obtained during the report period can be used to see the development from solar cycle 20 to cycle 21. Figure 1 displays the variation of monthly mean values of the five frequencies.

Though there are fluctuations one can see, in the main, the two cycles separated by a minimum. The minimum, for most frequencies is in the period 1975-76. In solar cycle 20 one can see the primary maximum around 1970 and the secondary maximum about 1972. The decline of solar cycle 20 about 1970 is interrupted by a secondary maximum about 1972. While the flux values of the four lower frequencies clearly decline during the minimum, that of 8800 MHz is less clear. The four lower frequencies show a drop of about 50% from maximum values. But if we consider the 8800 MHz data starting about November 1971 we can see the secondary maximum of 1972 but fail to see the steady decline starting in 1973. If the reason is to be found in the sun, then this is very interesting. When we consider the data so far for solar cycle 21, up to June 1979, we see the flux values approaching or exceeding levels during the previous solar cycle.

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PROTON EVENTS 1977-79

Ground Level Events, rare energetic events, occurred during the report period on 19 and 24 September 1977, 22 November 1977, 7 May 1978 and 23 September 1978. With some, the solar radio bursts associated were observed at Manila Observatory and will be described below. Also to be described are the radio bursts associated with proton events.

Proton events of 7 and 16 September 1977. A report of these events was prepared for publication (Badillo, 1979).

Proton events in October and November 1977. Two proton events, one on 12 October 1977 and another on 22 November 1977, appear to be indicated by the sharp increase of high energy protons detected by satellites. The radio bursts associated with the November event occurred after Manila observing hours but the radio burst of the October event was recorded and is shown in Figure 2. A magnetic sudden commencement storm occurred two days later. The recorded times and fluxes of the great burst are:

12 OCT 77

MHz	Start	Max	Dur	Type	Peak	Mean
8800	0151.4	0152.6	21.1	47	1190.	310.
4995	0151.4	0151.6	12.4	47	835.	172.
2695	0151.3	0151.6	11.7	47	610.	154.
1415	0151.1	0151.6	25.9	47	760.	126.
606	0150.4	0152.6	19.3	47	5600.	855.
24-48	0150.4	-	13.0	III	III	

A 1B flare in McMath region 14979 was observed at N07W07 with a maximum at 0152. The source site is favorable for particles to reach the earth. This is the second rotation period of the plage. The cm burst has the U-shaped spectrum and high intensities.

Proton events of January 1978. High energy protons were detected by satellites during both January and February 1978. While the energetic protons detectible in the early days of January could be as energetic and plentiful as those in February, the event in February was preceded by many days without protons so that the onset was unmistakable. There may have been many proton events in January, which would make it difficult to determine when one began and the other ended. Three January radio bursts are here selected because of their high fluxes, and are depicted in Figures 3-5. There is a similarity in the shape of the curves, an almost triangular shape preserved with the different bursts. Their spec-

tra too are similar, with flux increasing with observing frequency. They arose from McMath Region 15081 as it was about to reach the west limb. Tabulated with the solar radio data are the hydrogen alpha flares.

7 JAN 78

MHz	Start	Max	Dur	Type	Peak	Mean
8800	0633.6	0638.3	24.9	47	2250.0	135.0
4995	0633.5	0638.6	23.0	47	2200.0	1200.0
1415	0633.8	0639.2	20.2	4	215.6	138.6
606	0633.0	0637.5	7.5	4	86.8	56.4
24-48	0343.5	-	175.0	IV	III	
H-alpha	0632	0637U		1N	(S15W64)	

8 JAN 78

MHz	Start	Max	Dur	Type	Peak	Mean
8800	0208.3	0212.8	11.8	47	810.0	506.0
4995	0208.3	0213.0	12.3	47	515.0D	343.2D
1415	0208.2	0210.3	12.9	4	279.0	175.0
606	0208.6	0212.5	11.6	47	2100.0	1300.0
24-48	0208.5	-	2.1	III	I	
H-alpha	0210	0216		1N	(S12W80)	
H-alpha	0210	0237		2N	(S12W80)	

8 JAN 78

MHz	Start	Max	Dur	Type	Peak	Mean
8800	0708.0	0713.8	18.5	47	986.7	658.0
4995	0708.0	0714.3	18.5	3	344.8	218.0
1415	0709.0	0712.6	10.5	3	63.6	41.3
606	0709.8	0712.2	4.7	3	114.1	72.0
24-48	None					
H-alpha	0710	0713		2B	(S12W85)	

Proton event of February 1978. Associated with the proton flare of February is this radio event observed at Manila Observatory and depicted in Figure 6. The shape is different from that of the January radio bursts. The burst has the nature of a slow rise and fall, a long rise time and smooth featureless curve. Peak intensities are not remarkably high. The event is of long duration especially in the 1415 MHz range. The latter part was first rejected as noise but considering the energetic protons

detected later it is here included for possible significance. The dekame-
 ter event was lengthy. The hydrogen alpha flare data are tabulated with
 the associated radio event. There are a number of them indicating fla-
 ring at different times and sites. The western source site is favorable
 for protons to reach the earth.

13 FEB 78

MHz	Start	Max	Dur	Type	Peak	Mean
8800	0135E	0202.0	60D	3	317.3	212.0
4995	0135E	0202.5	60D	3	408.0	272.0
2695	0135E	0205.5	60D	47	737.1	491.4
1415	0135E	0205. U	60D	3	474. D	316. D
606	0135E	0208.7	60D	3	288.6	192.0
24-48	-	0314.2*		CONT	I	
H-alpha	0139	0151		1B	(N13W24)	
H-alpha	0139	0143		1N	(N13W24)	
H-alpha	0140	0150		1B	(N19W14)	
H-alpha	0140	0143		-F	(N10W14)	

* End time

Ground Level Event of May 1978. Between 24 April and 9 May 1978 solar rotation carried McMath region 15266 across the solar disk. During this period there were many and intense events. In particular the events of 7 May 1978 may be singled out because there was a Polar Cap Absorption, there were energetic protons detected by satellites and there were cosmic rays detected by neutron monitors. The solar radio event that may be associated with these events was recorded at Manila and is depicted in Figure 7. Tabulated with the solar radio data is the hydrogen alpha flare. The flare data helps to locate the site of radio emission, a western site favorable for protons to reach the earth. The radio event is quite complex showing pulsations. The spectrum of the peak fluxes around 0330 UT is U-shaped. The later maxima at the 606 MHz range become larger. There are corresponding maxima in the higher frequencies, thus it was considered useful to tabulate also those lesser maxima.

7 MAY 78

MHz	Start	Max	Dur	Type	Peak	Mean
8800	0322.2	0328.5	39.4	47	3450.0	1175.0
		0329.4		47	3450.0	
		0352.8		46	171.5	
		0358.5		46	169.7	
4995	0319.3	0328.6	50.8	47	1400.0	550.0
		0329.7		47	1640.0	
		0352.9		45	177.3	
		0358.8		45	175.3	
2695	0321.7	0332.7	48.2	47	765.0	250.0
		0335.4		47	740.0	
		0353.1		45	196.0	
		0358.8		45	176.4	
1415	0322.8	0327.5	46.7	46	330.0	120.0
		0352.8		45	151.4	
		0359.2		45	176.4	
606	0324.0	0330.5	49.2	47	690.0	240.0
		0352.7		47	845.0	
		0359.7		47	1010.0	
24-48	0329.9	-	21.6	CONT	III	
H-alpha	0336E	0336U		2N	(N24W68)	

Proton event of February 1979. That an event of some magnitude was going on was indicated by the extent of the flares and size of the radio bursts. This is listed in the Table below.

16 FEB 79

MHz	Start	Max	Dur	Type	Peak	Flux
8800	0148.4	0151.6	10.9D	4	462.5D	154.2D
4995	Outage					
2695	0141.8	0149.7	134.0	47	937.1	7000.0
		0229.3			30000.0	
1415	0143.0	0149.7	133.0	47	684.4	15000.0
		0231.6			88000.0	
606	0145.8	0151.7	130.8	47	1095.2	700.0
		0229.9			3080.0	
24-48	0153.0	-	10.0	III	II	
H-alpha	0144.	0152.	95.	3B	(Mitaka)	
H-alpha	0145.	0152.	63.	2B	(Palehua)	
H-alpha	0314.	0317.	30.	2B	(Mitaka)	

The solar region responsible was McMath region 15830 then located at N15E54. Energetic protons in the 10 MeV range reached the earth about 42 hours after the flare, while particles causing the magnetic sudden commencement reached the earth another seven hours later. The time delay is quite large which could be due to the unfavorable eastern site of the flare area. The time development of the radio flare is shown in Figure 8 which shows the second part of the radio burst. Not shown is the part corresponding to the maximum of the first flare at about 0152UT, but the data is tabulated in the Table above. The 8800 MHz equipment failed almost after the maximum. Using the radio flux with maximum at about 0151UT, we can see a U-shaped spectrum. However for the second part, with the greater flux values after 0220UT, we no longer have the U-shaped spectrum. The flares and the radio burst are of long duration.

Proton event of April 1979. As of this writing, the event is not a PCA or satellite proton event, but it is connected with a major magnetic storm. The fluctuations and the higher flux values are in the higher frequencies, but the U-shaped spectrum is not evident. The time development of the radio flare is shown in Figure 9 and tabulated values are listed below.

27 APRIL 1979

MHz	Start	Max	Dur	Type	Peak	Mean
8800	0638.0	0646.4U	24.0	47	3470.0D	2150.0D
4995	Outage					
2695	0639.0	0646.4	23.0	47	652.8	421.9
1415	0639.0	0646.4	23.0	4	269.8	179.9
606	0639.0	0647.1	23.0	4	270.0	180.0
24-48	0651.8	-	5.4	III G	I	
H-alpha		0652.		1B	(N18E16)	

Proton event of June 1979. The intense solar radio burst on 5 June 1979 was followed by satellite protons, a PCA and a sudden commencement about 38 hours later. Radio emission extended to the meter bands but did not reach the dekameter bands. The time development of the radio burst is given in Figure 10. The time of the maximum value of the flux is different at the observing frequencies, occurring earliest at the lowest frequency. The duration was long both at radio wavelengths and in hydrogen alpha. In the radio frequencies separate peaks occur and to some of these are associated some flaring maxima. The eastern site of the source region may account for the long delay of the PCA protons.

Tabulated data are indicated below:

5 JUNE 79

MHz	Start	Max	Dur	Type	Peak	Mean
8800	0503.0	0533.7	71.0	47	4400.	1500.
4995	0502.0	0533.7	72.0	47	3500.	1200.
2695	0502.0	0533.7	72.0	47	4400.	1600.
1415	0502.0	0520.5	72.0	47	14300.	3000.
606	0502.0	0517.2	64.0	47	15000.D	2000.
24-48	None					
H-alpha	0508.0E	0514.0U	84. D	1B	(N20E16)	
		0529.0U		1N		

SUMMARY

The daily radio patrol of the sun at cm and dekameter wavelengths at Manila Observatory complemented the daily radio patrol at Sagamore Hill Radio Observatory. Daily flux values and distinctive events were recorded, tabulated and published. Of the many radio flares in the report period, about six were connected to Ground Level Events and energetic proton events.

ACKNOWLEDGEMENT

We are grateful to Mr. William R. Barron for providing needed encouragement. This research was funded by Air Force Geophysics Laboratory.

REFERENCE

Badillo, V. L., Solar radio bursts of 7 and 16 September 1977. Upper Atmosphere Geophysics Report (1979) in press.

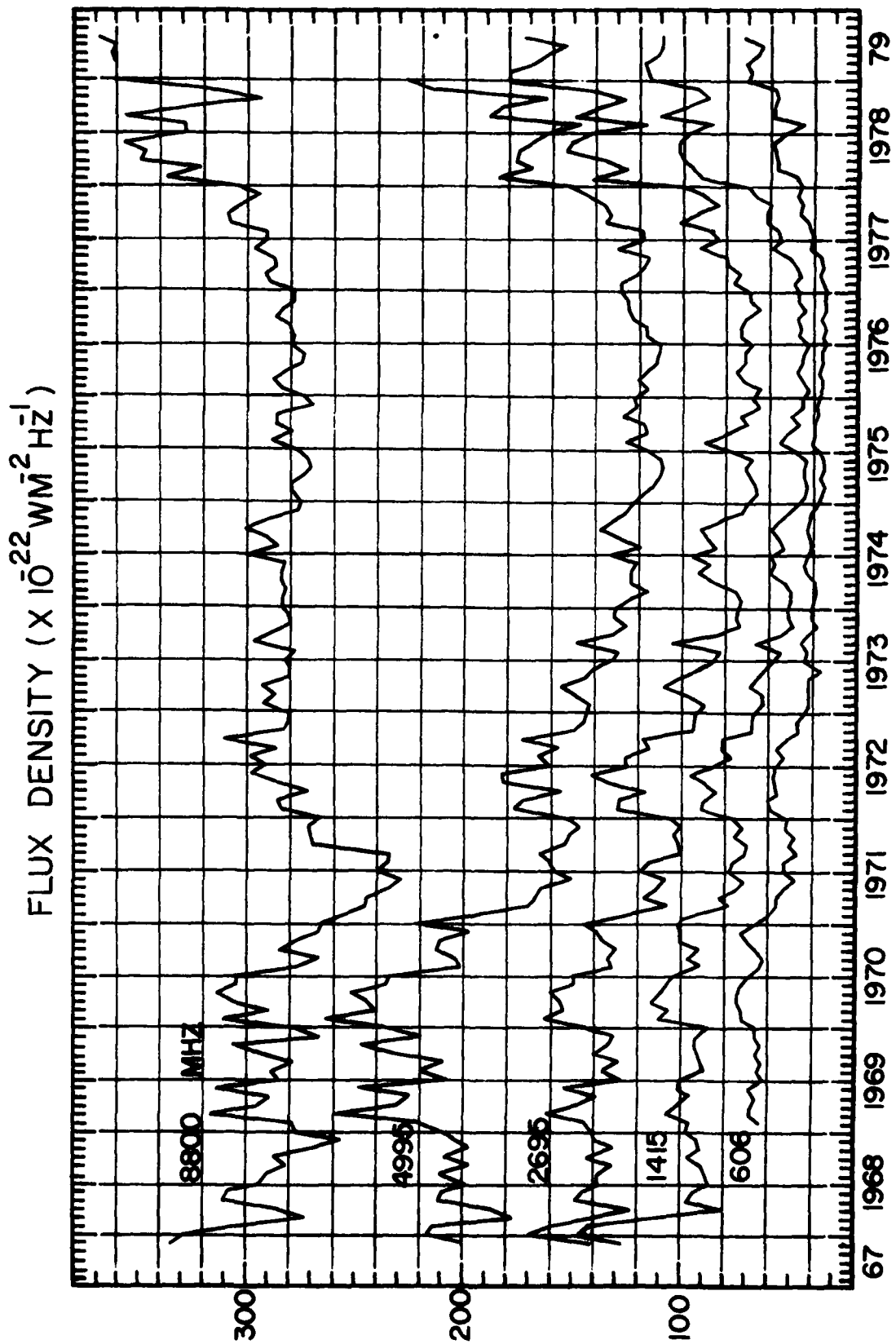


FIG. 1 1967-79 MONTHLY MEAN FLUX AT MANILA OBSERVATORY

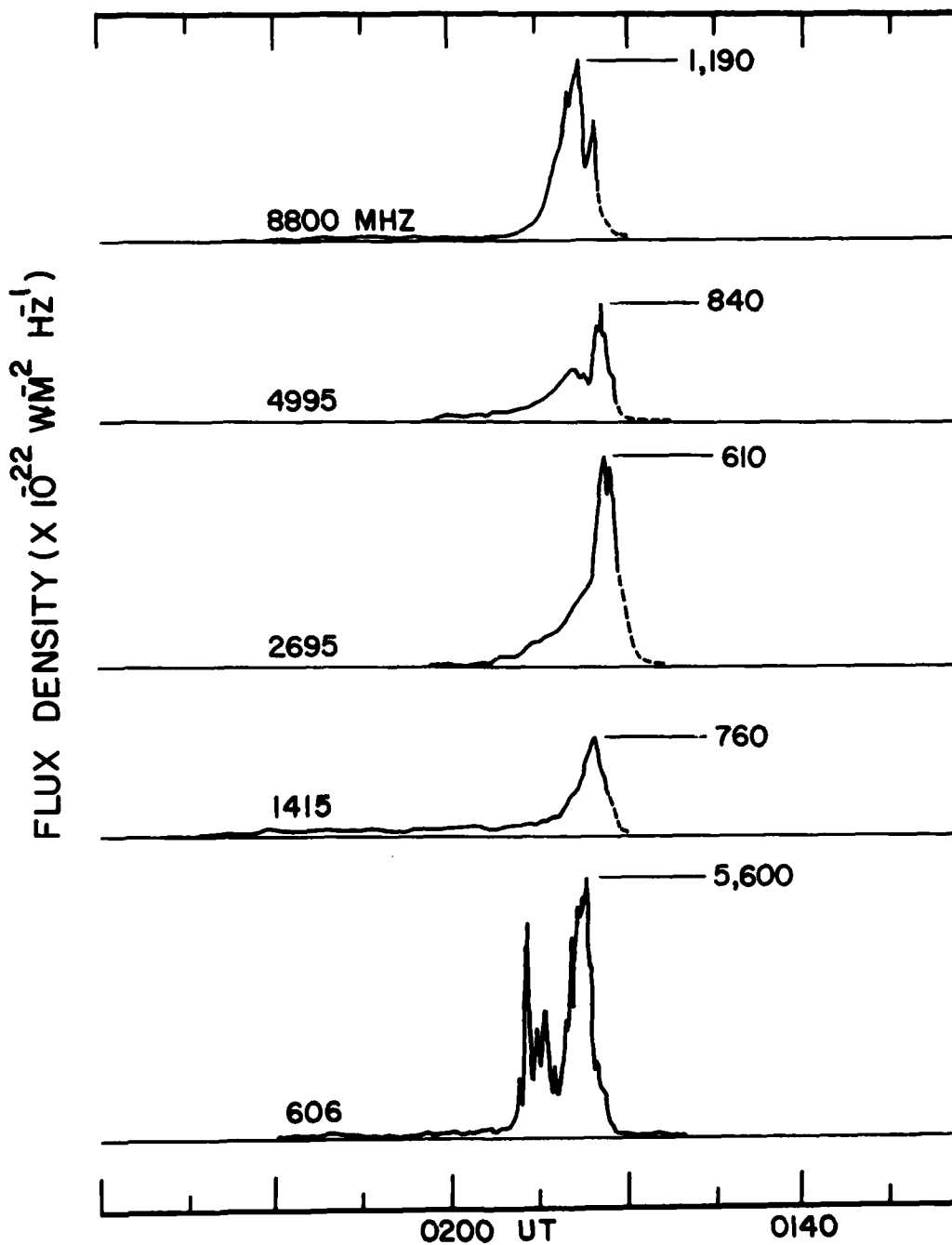


FIG.2 BURST OBSERVED ON 12 OCT 1977 AT MANILA OBSERVATORY. (START AND MAXIMUM TIME UNCERTAIN DUE TO IF LUX CALIBRATION IN PROGRESS.)

FLUX DENSITY (X 10^{22} WM^{-2} HZ^{-1})

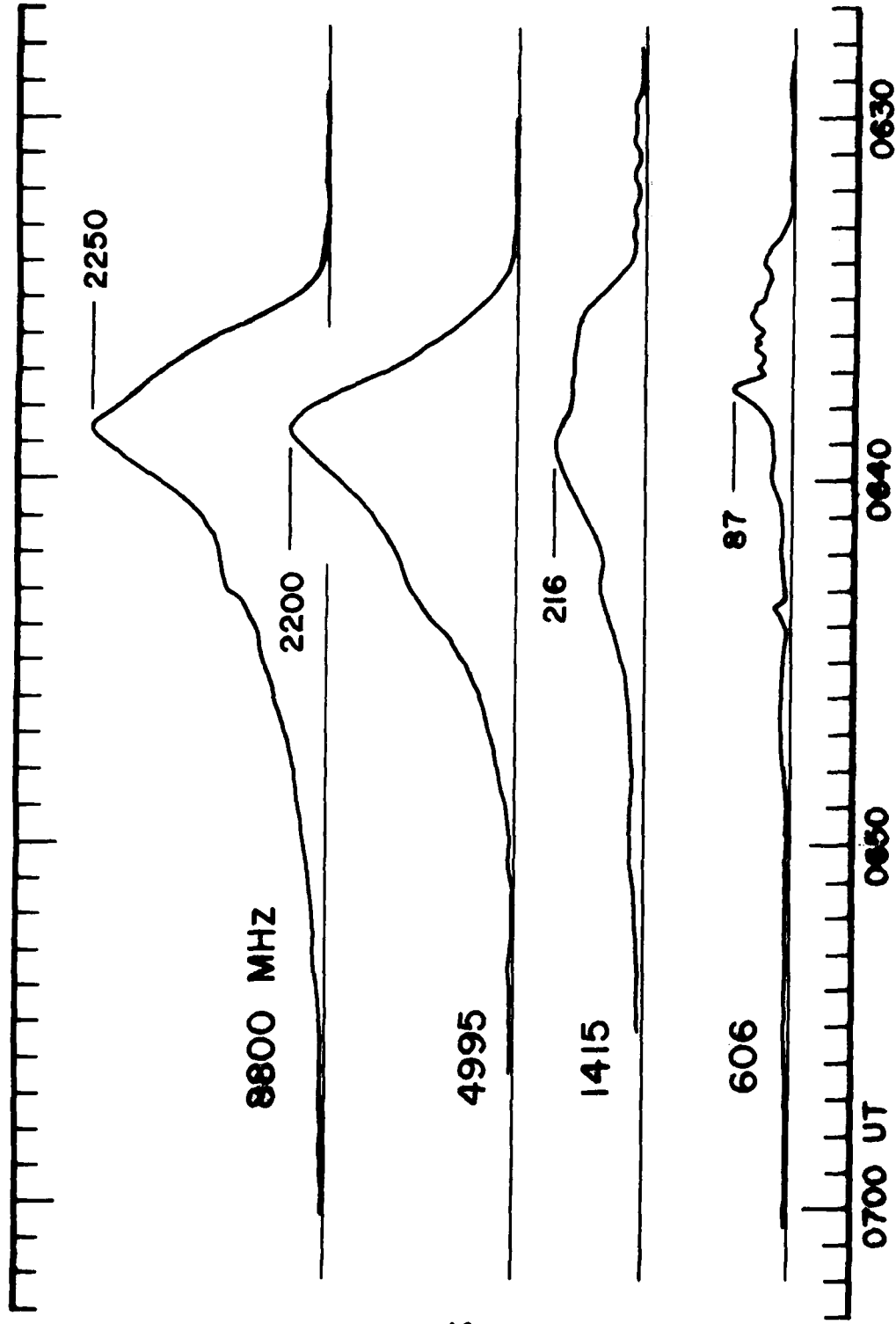


FIG. 3 SOLAR BURST OBSERVED ON 7 JANUARY 1978 AT
MANILA OBSERVATORY. OUTAGE ON 2695 MHZ.

FLUX DENSITY ($\times 10^{-22} \text{ WM}^2 \text{ Hz}^{-1}$)

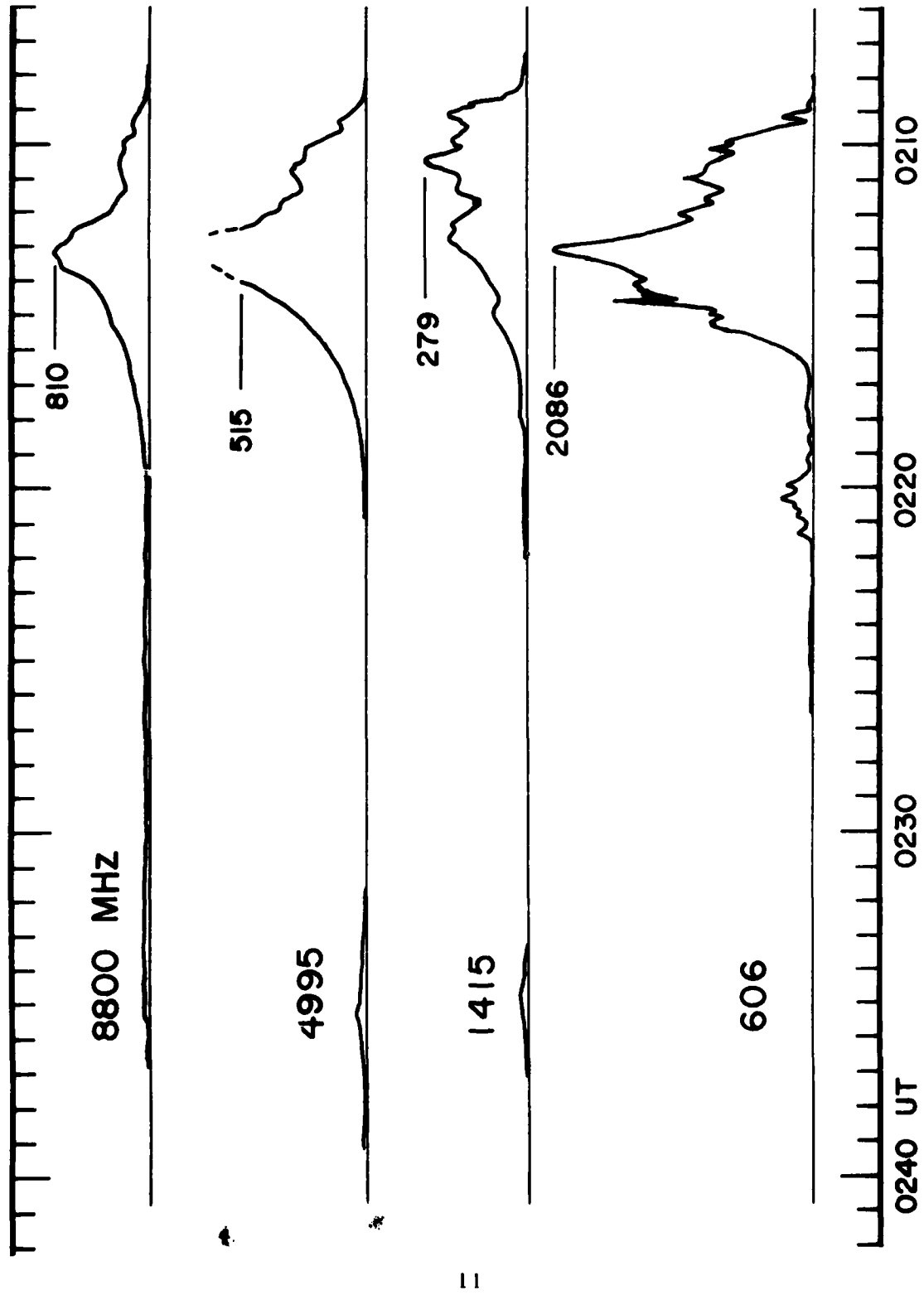


FIG. 4 SOLAR BURST OBSERVED ON 8 JANUARY 1978 AT
MANILA OBSERVATORY. OUTAGE ON 2695 MHZ.

FLUX DENSITY ($\times 10^{22} \text{ WM}^{-2} \text{ Hz}^{-1}$)

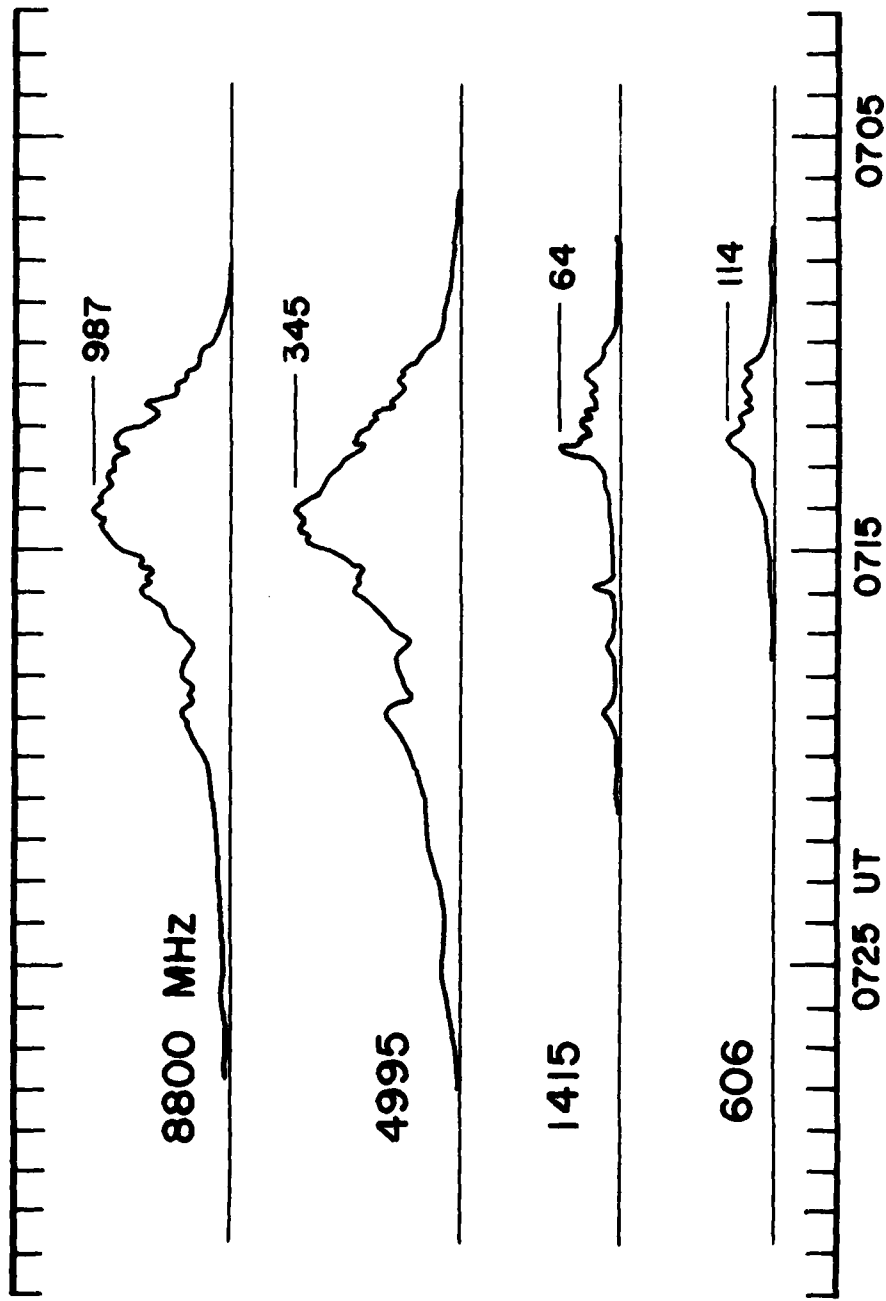
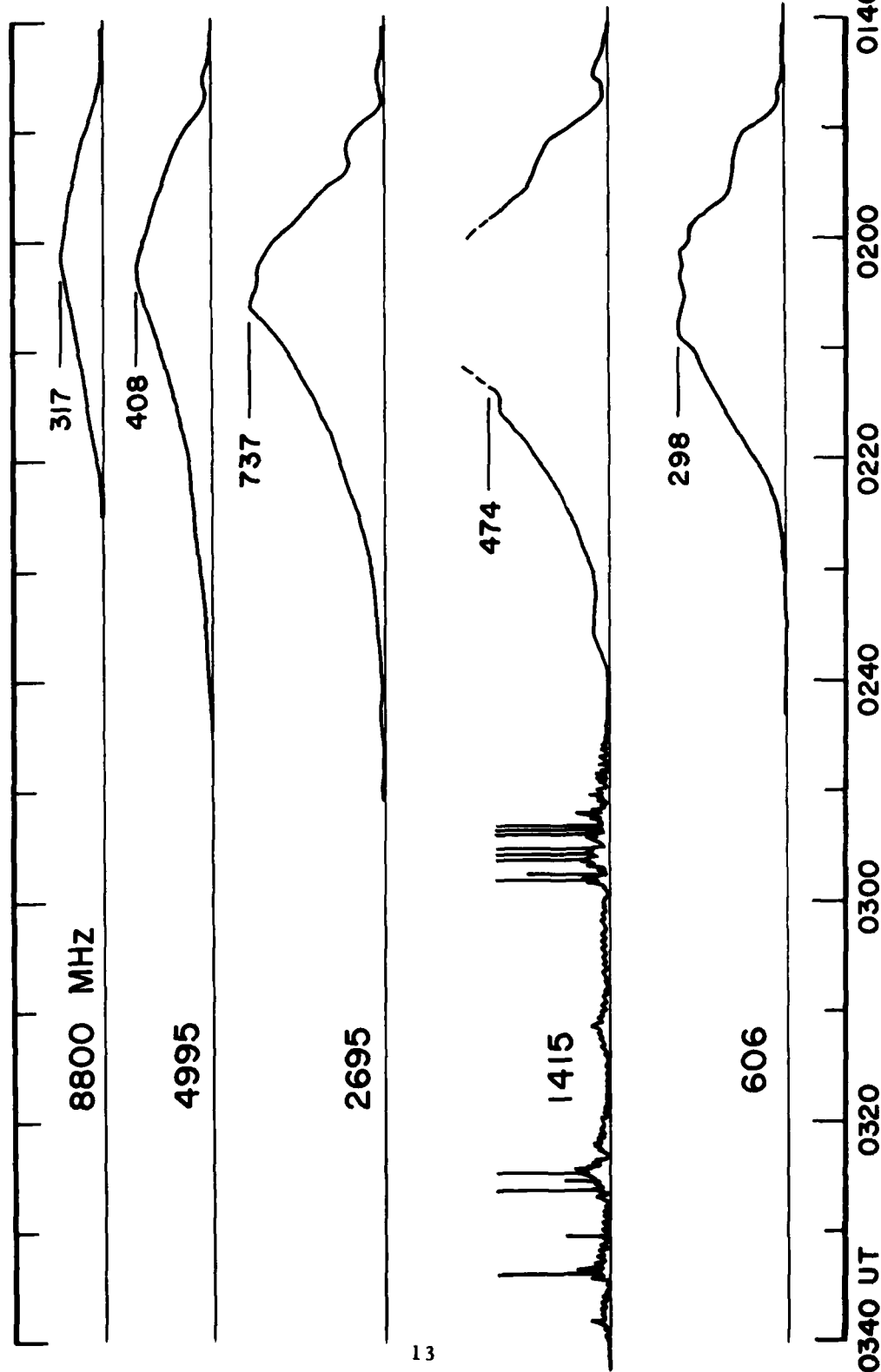


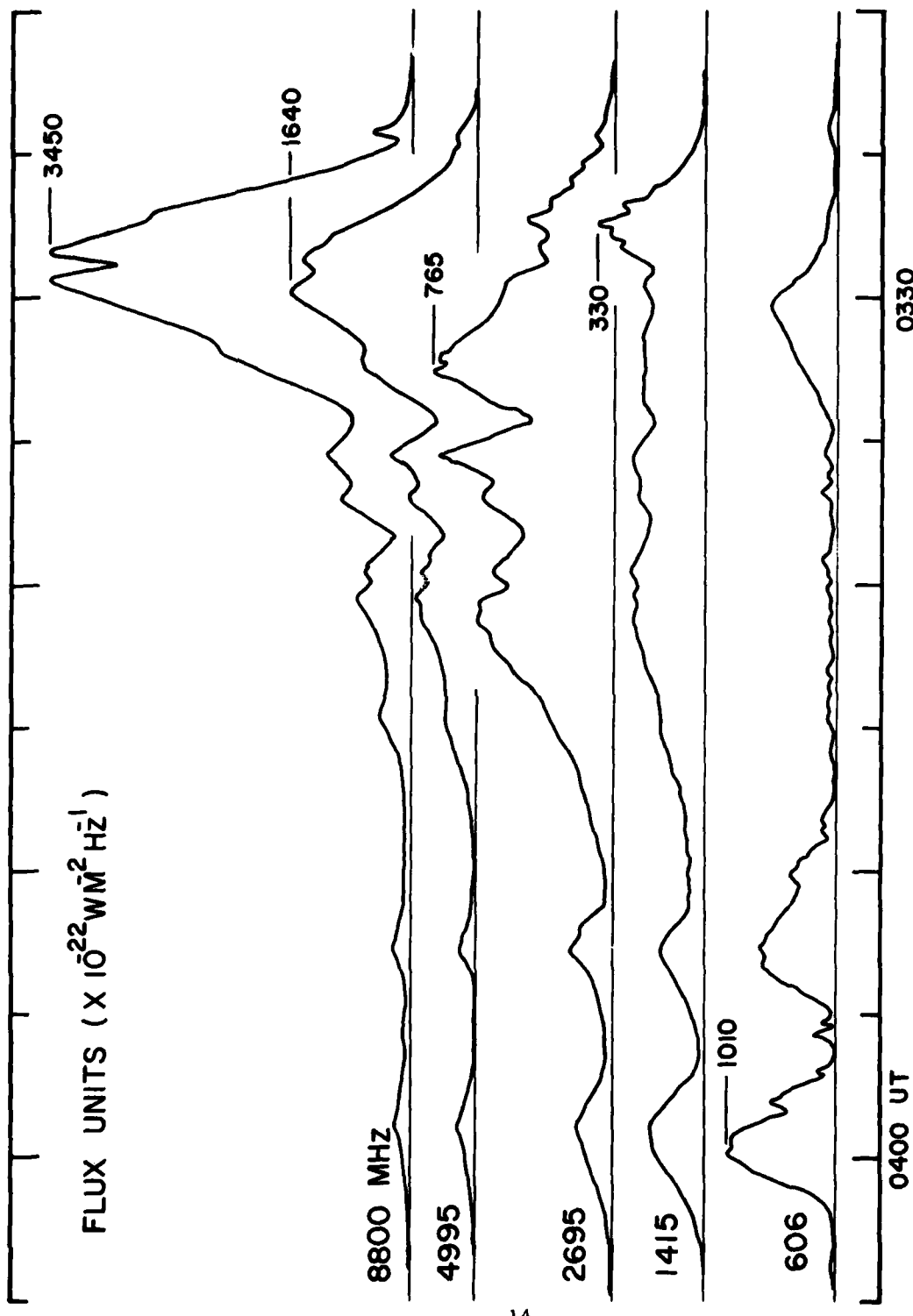
FIG.5 SOLAR BURST OBSERVED ON 8 JANUARY 1978 AT
MANILA OBSERVATORY. OUTAGE ON 2695 MHZ.

FLUX DENSITY ($\times 10^{-22} \text{ WM}^{-2} \text{ HZ}^{-1}$)



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FIG. 6 BURST OBSERVED ON 13 FEBRUARY 1978 AT MANILA OBSERVATORY



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FIG. 7 SOLAR BURST OBSERVED ON 7 MAY 1978 AT MANILA OBSERVATORY

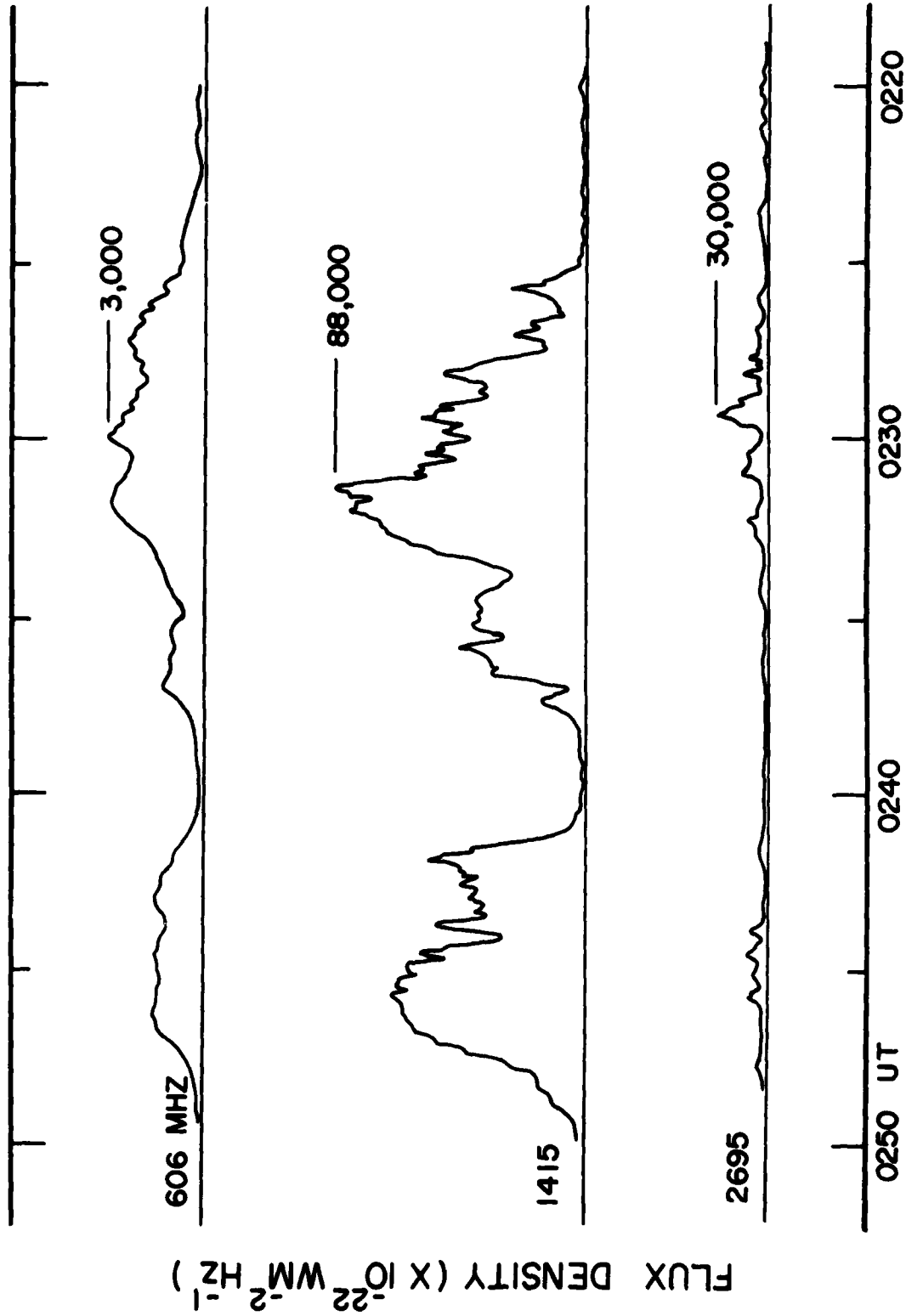


FIG.8 BURST OBSERVED ON 16 FEBRUARY 1979 AT MANILA OBSERVATORY
 START TIME 0142. END TIME 0356.(OUTAGE OF 4995 AND 8800 MHZ)

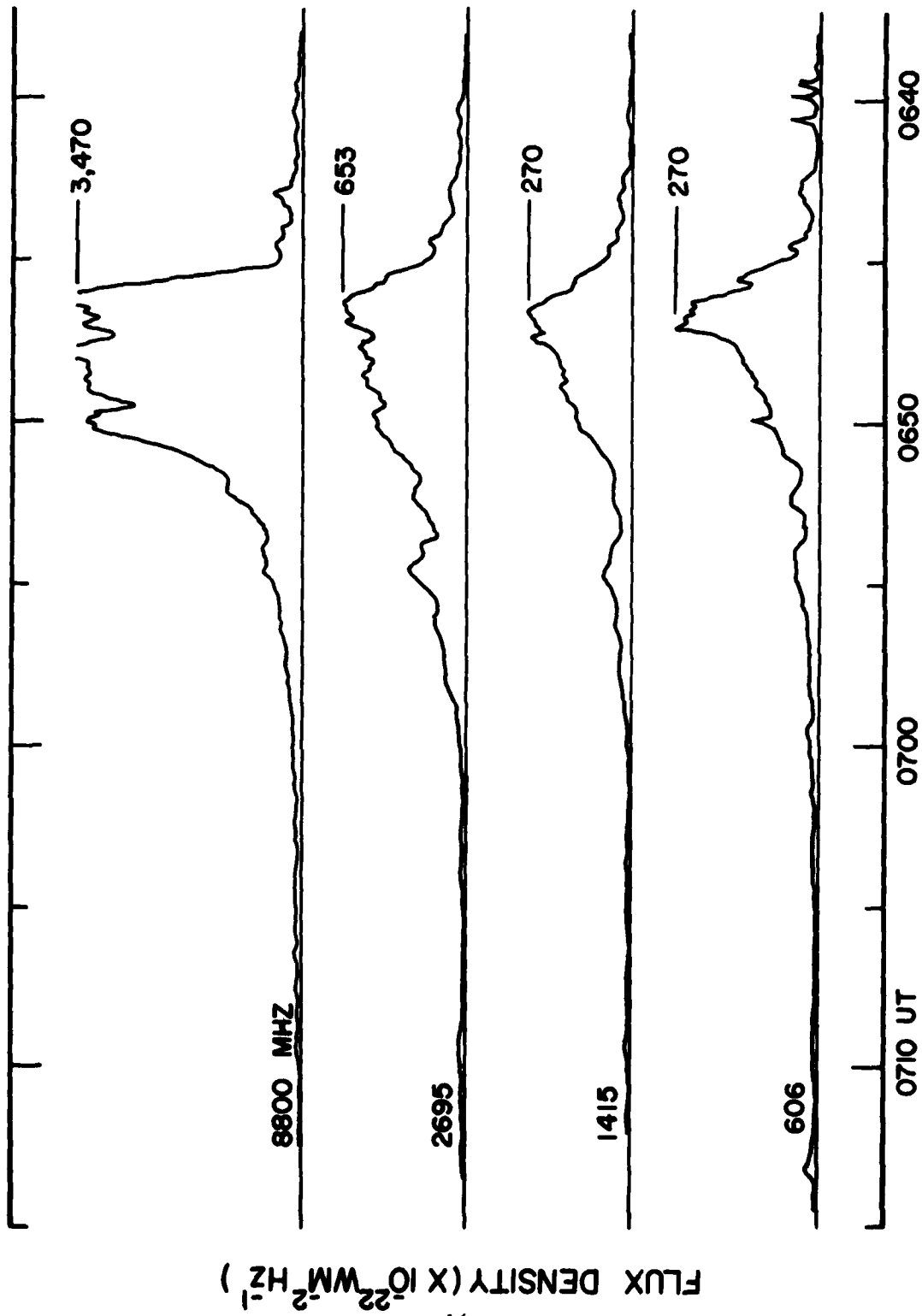
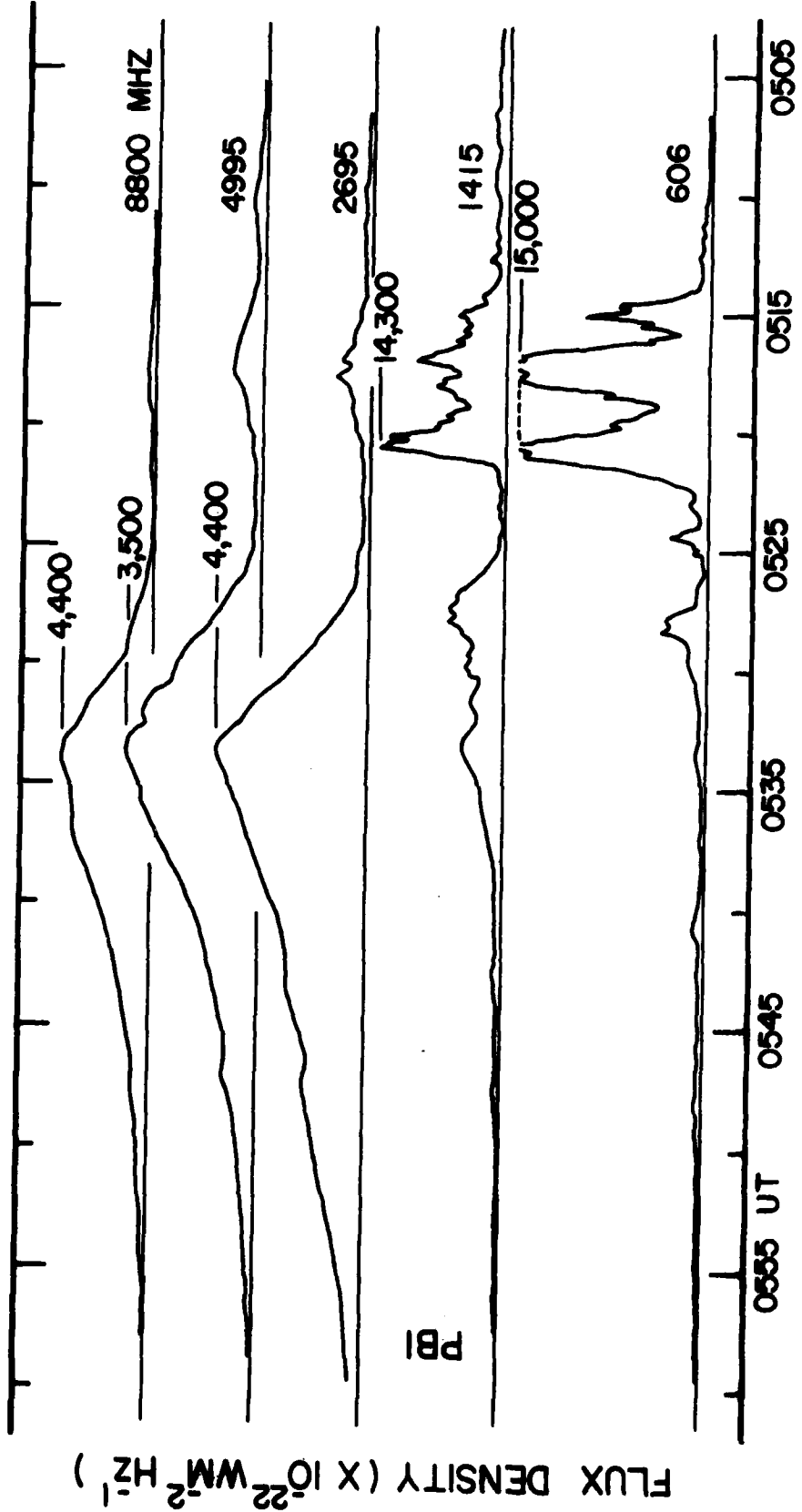


FIG. 9 BURST OBSERVED ON 27 APRIL 1979 AT MANILA OBSERVATORY
(OUTAGE OF 4995 MHZ)



FLUX DENSITY (X 10²² WM⁻² HZ⁻¹)

FIG. 10 SOLAR BURST OBSERVED 5 JUNE 1979 AT MANILA OBSERVATORY