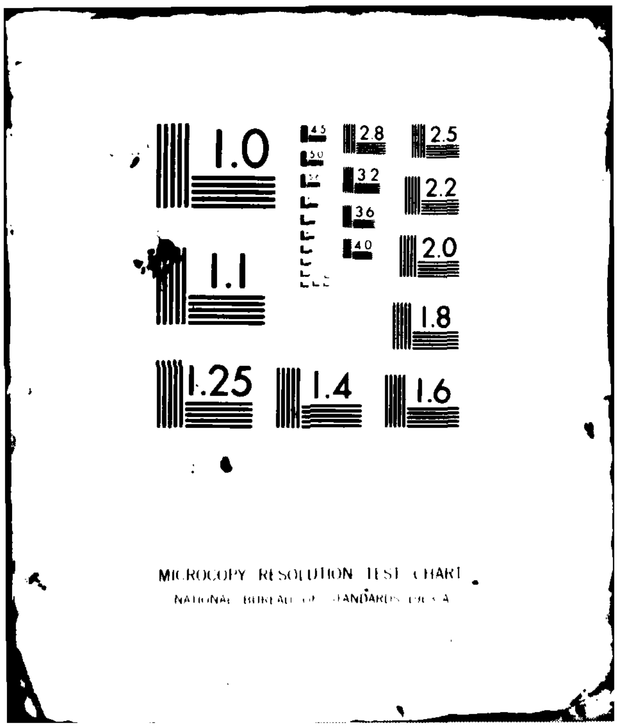
AD-A113 084 CALIFORNIA INST OF TECH PASADENA F/G 3/2
INTERFEROMETRIC MICROWAVE POLARIMETRY AS A TOOL FOR SHORT-TERM --ETC(U)
AUG 81 G J HURFORD F19628-81-K-0028
UNCLASSIFIED SR-1 AFGL-TR-81-0312 NL

END
DATE
FILMED
4 82
DTIC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFGL-TR-81-0312	2. GOVT ACCESSION NO. AD-A113 084	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INTERFEROMETRIC MICROWAVE POLARIMETRY AS A TOOL FOR SHORT-TERM SOLAR FLARE PREDICTION		5. TYPE OF REPORT & PERIOD COVERED Scientific Report No. 1
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) G. J. Hurford		8. CONTRACT OR GRANT NUMBER(s) F19628-81-K-0028
9. PERFORMING ORGANIZATION NAME AND ADDRESS California Institute of Technology 1201 E. California Blvd. Pasadena, CA 91125		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102F 2311G3BG
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory Hanscom AFB, Massachusetts 01731 Monitor/Donald A. Guidice PHG		12. REPORT DATE August 1981
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Interferometric microwave polarimetry
Solarflare prediction
Owens Valley Radio Observatory
Preflare microwave activity
10.6 GHz interferometric observations

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this study is to look at a data base of interferometric solar microwave data in order to identify, evaluate and interpret preflare microwave signatures, with reference to their possible role in the short-term prediction of solar flares. The data base used was acquired by the Owens Valley solar interferometer at 10.6 GHz between February 19, 1980 and March 31, 1981. Reserving the second half of this

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. data base for verification of tentative results, 27 major flares occurring between February 19 and August 31, 1980 were selected using optical, soft x-ray OR microwave flux criteria for which good quality interferometric data was available. These events were analysed in detail and very similar preflare signatures noted in four (15%) of the cases. Other unusual preflare behavior was noted in four additional cases. The most common signature was a step-like increase in signal amplitude, accompanied by a decrease or reversal in the degree of polarization. Such a signature occurred between a few minutes to a few tens of minutes before the start of the impulsive phase. Optical data, available in three cases, showed the microwave changes were simultaneous with either small brightenings or small-scale filament disruptions. Preliminary results show that such microwave behavior occurs far too seldom for such an association with major flares to be a chance occurrence.

INTERFEROMETRIC MICROWAVE POLARIMETRY
AS A TOOL FOR SHORT-TERM SOLAR FLARE PREDICTION

G. J. Hurford
California Institute of Technology

ABSTRACT

The purpose of this study is to look at a data base of interferometric solar microwave data in order to identify, evaluate and interpret preflare microwave signatures, with reference to their possible role in the short-term prediction of solar flares. The data base used was acquired by the Owens Valley solar interferometer at 10.6 GHz between February 19, 1980 and March 31, 1981. Reserving the second half of this data base for verification of tentative results, 27 major flares occurring between February 19 and August 31, 1980 were selected using optical, soft x-ray OR microwave flux criteria for which good quality interferometric data was available. These events were analysed in detail and very similar preflare signatures noted in four (15%) of the cases. Other unusual preflare behavior was noted in four additional cases. The most common signature was a step-like increase in signal amplitude, accompanied by a decrease or reversal in the degree of polarization. Such a signature occurred between a few minutes to a few tens of minutes before the start of the impulsive phase. Optical data, available in three cases, showed the microwave changes were simultaneous with either

small brightenings or small-scale filament disruptions. Preliminary results show that such microwave behavior occurs far too seldom for such an association with major flares to be a chance occurrence.

I. INTRODUCTION

The purpose of this study is to look at a moderate size data base of interferometric solar microwave data in order to identify, evaluate and interpret preflare microwave signatures. In terms of Martin's (1980) terminology, this study is dealing with "distinct" preflare events -- that is, events which are characterized by irreversible, continuous changes culminating in the o currence of a flare, as opposed to evolutionary or statistical association of active region characteristics with the general level of solar activity. In this context, we define preflare events as those events occurring before the start of the impulsive phase.

II. MICROWAVE OBSERVATIONS

The study is based on observations obtained with the Owens Valley Solar Interferometer (Zirin, Hurford and Marsh 1978) which obtained solar observations at 10.6 GHz up to 8 hours per day almost daily from February 19, 1980 until March 31, 1981. The instrumentation consisted of a pair of 27 m fully steerable parabolic antennas (half power beam width of 4.4 arc-min at 10.6 GHz) deployed on either a 700 foot east-west baseline (until 1980 June 29) or a 450 foot northwest to southeast baseline. The fringe spacing on the sun varied between 0.5 and 2 arc minutes, depending on date and time of day. Occasionally, a 40 m antenna was added to the system to enable 3-element interferometry with fringe spacing as short as 4.6 arc-seconds.

The original data was acquired with 50 msec time resolution (occasionally 25 or 100 msec), recorded and archived on magnetic tape. Appropriate time averaging was introduced during the data analysis. The system observed alternately in left and right circular polarization, with all active signal processing common to both polarizations. Therefore,the system sensitivity to polarization changes was very good.

In general, the observing routine consisted of brief observations of a cosmic source (for amplitude and phase calibration) alternating with 60 to 90 minute observations of an active region. The choice of active region was generally based on the Solar Maximum Mission observing program or a region likely to produce flares, as determined by optical evaluation at Big Bear Solar Observatory.

The overall methodology of the study was to identify a set of major flares for which we had interferometric observations both of the impulsive phase and of the preflare situation. The preflare microwave activity was then examined in detail to identify any potential unusual behavior, that is changes in any aspect of the microwave signal that could not be attributed to the normal change in amplitude, phase or apparent degree of polarization due to the rotation of the earth and consequent change in the fringe spacing or orientation. (As discussed by Kundu and Alissandrakis(1975), such effects can cause a stable source to display a variable interferometric signature.) Changes due to known instrumental effects, such as pointing, tracking or atmospheric effects were also disregarded. The sensitivity of the system to preflare changes varied markedly from event to event. In some cases, where the active region structure was simple, a very stable interferometric response was observed and relatively subtle preflare signatures would have been readily apparent. In other cases, the interferometric output varied significantly through much of the day, due to a more complex distribution of microwave sources within the field of view and/or frequent (but minor) flaring activity. In such cases, only relatively gross preflare signatures changes could be identified.

The criterion chosen to define major flares for this purpose was that a flare had to have either optical importance 1 or greater, soft X-ray class M1 or greater, or 10.6 GHz flux density of 50 sfu or greater. Such a criterion was adopted so that an adequate number of events would be available for careful study and so that no preference would be given to one type of flare over another.

The time period examined at this stage was limited to Feb 19, 1980 to August 31, 1980, thus leaving a comparable period available for a subsequent test of any preflare signatures identified.

Initially, an overcomplete list of 46 flares was identified as possibly meeting such criteria. These events were then studied in detail and, in some cases, deleted from further study on the basis of data quality, inadequate preflare coverage, etc. The presence or absence of precursors was not a consideration in such rejection. The final list of 27 'major' flares occurring in this time period and for which satisfactory OVRO data was available is shown in Table 1. The data for these flares has been reduced and plotted, first with 10-second averages in Stokes R and L, on logarithmic scales. Such plots effectively display small variations in circular polarization since the linear separation of the amplitudes corresponds to the degree of polarization. Additional displays, optimized for each event, were generated as needed and examined in detail. Since the purpose of this work was to identify distinct preflare events rather than those of a more evolutionary character, each day was analyzed independently, and no formal attempt was made to compare the interferometric signatures from day to day.

Examination of the preflare microwave data for the 27 major flares identified in Table 1 showed very similar preflare microwave signatures in four cases, with other microwave changes in four others. Optical data from Big Bear Solar Observatory was also examined and will be referred to below.

III. DISCUSSION OF INDIVIDUAL EVENTS

In this section we will discuss the preflare microwave behavior for the eight events that showed some type of preflare changes not attributable to the instrumental causes.

A/ March 23, 1980.

The beginning of the impulsive phase of this event at 1655 was preceeded by a pair of step-like increases in the left circularly polarized (LCP) signal at 1648 and 1651, accompanied by smaller increases in the right circularly polarized (RCP) amplitude (Figure 1). The result was that the polarization had reversed from RCP to LCP four minutes before the impulsive phase began, and that the overall amplitude in Stokes I more than doubled. Optically, the first step coincided with the lifting off of one leg of a Y-shaped filament (Figure 2). The second step coincided with the disintegration of the other leg, leaving only the base. The impulsive phase began about 4 minutes later. The impulsive and decay phases of this microwave event are discussed in detail elsewhere (Marsh et al. 1981).

B/ May 15, 1980.

The M2 event at 2047 (Figure 3) was preceeded in this case by evolution of the active region polarization beginning at about 1935. This was qualitatively similar to the preceeding case, except on a much slower time-scale. Note the dramatic reduction and reversal in the sense of polarization starting at 1935, which followed a relatively stable morning. It is important to note that the sun was at the local meridian at about this time. With the stable meridian fringe spacing accociated with an east-west baseline at the local meridian, it is therefore very unlikely that the polarization change that occurred following 1935 represented anything other than a real temporal change in the source. Note also the return of the polarization to its preflare state following the event.

C/ June 19, 1980.

The event at 1839, shown in Figure 4, was clearly preceeded by a steplike increase at 1832, with some reduction in degree of polarization. Amplitudes before and after this event were very stable. Optical data, shown in Figure 5, show that this step was associated with a continuing development of a small optical brightening.

D/ July 1, 1980.

This Class X2 flare was indeed a major flare featuring not only gamma ray and white light emission, but also magnetic transients (Zirin and Neidig,1981; Zirin and Tanaka, 1981). The impulsive phase of this event began at 1626 UT, early in the day at OVRO, but after a significant decrease in polarization at 1619 with the same character as the events discussed above. This preflare microwave signature coincided with optical brightening in a well defined compact loop as shown in Figure 7.

E/ July 12, 1980

The two events on July 12, 1980 (Figure 8) each showed a striking decrease in their signal amplitudes, accompanied by a decrease in polarization. In noting the contrast to the previous cases, it should be recalled that the presence of a new microwave source in the field of view of an interferometer can result in a decrease in the resulting amplitude. (This occurs because the contributing sources add vectorially, not as scalars, in determining the final amplitudes.) Thus, it is conceivable that the decrease was due to the addition of a new source. Optically, there was almost continual low level activity during this time.

F/ April 11, 1980

The event at 2312 on April 11 occurred on an otherwise-quiet day which featured a relatively stable microwave profile until a small event occurred at 2259 UT(Figure 9). The feature of note, however, is not the occurrence of this event, but rather the failure of the microwave profile to return to its previous level after this event was over. Instead, it remained at a stable, enhanced level until the major flare began at 2310. Note also the reversal in polarization between 2336 and 2348.

G/ May 16, 1980.

The impulsive flares at 2205 and 2210 (Figure 10) occurred in AR2456 and left the active region amplitudes in an enchanced, stable state. The major flare in terms of soft x-rays occurred at 2232 following this enhancement. In this case the correlation may be deceptive, however, for optically the event at 2232 occured in what appeared to be a magnetically separate part of the active region. Furthermore, close examination of Figure 10 shows that the preflare enhancement remained after the event at 2232. The decrease at 2240 is a remarkable case, discussed elsewhere (Hurford and Tang 1981), in which a surge, originating in the event at 2232, occulted the compact source of emission of the active region.

IV. DISCUSSION

Four of the cases discussed above display a common characteristic. A few minutes or tens of minutes before a major flare, a signficant step-like increase in fringe amplitude occurs, accompanied by a decrease or reversal in the degree of polarization. It then remains at an enhanced state until the occurrence of the major flare. In some cases, the increases were accompanied by small brightenings in H-alpha, brightenings which otherwise might not be exceptional. The polarization sense suggests that these sources were preferentially occurring in the weaker, rather than the stronger fields.

Physically, it is tempting to identify these preflare sources with the onset phase emission (van Hoven et al., 1980) observed in both soft X-rays and EUV by Skylab, since the events are similar both in temporal characteristics and frequency of occurrance.

To address the question of whether such a microwave signature is statistically significant, we have begun to examine the entire data base to see how often such behavior occurs without a major flare following within a few minutes. This effort, aided by a computer program, ONSET, examines a data stream of partially analysed OVRO data and issues predictions of impending flares based on the signature discussed above. Preliminary results indicate that such signatures occur much too infrequently for the association with major flares to be due to coincidence.

V. ACKNOWLEDGEMENTS

I wish to thank Dr. Kenneth Topka for compiling the list of major flares, Frances Tang for her analysis of the optical data, Margaret Liggett and Dan Zirin for their assistance with the analysis of the radio data, Jeff Nenow for preparation of the photographs, Dr. Harold Zirin for valuable discussions and Dr. Fred Erskine of University of Maryland for permission to use his observations of the May 15 event.

The analysis performed under this effort (Contract F19628-81-K-0028) makes use of OVRO observations funded by the National Science Foundation under Grant AST79-16149-A01.

TABLE 1 -- LIST OF 'MAJOR' FLARES WELL-OBSERVED BY OVRO

---DATE----	-UT-	OPTICAL	SOFT X-RAY	LOCATION	REGION
1980 FEB 20	2016	1B	C7	S08E28	AR2287
1980 FEB 25	2005	1B		N10E90	
1980 MAR 23	1658	1B	C7	S28W49	AR2339
1980 APR 10	1925	1N		N19W36	
1980 APR 11	2312	1N	M1	N10W70	AR2372
1980 APR 30	2026	SN	M2	S13W90	AR2396
1980 MAY 01	1840	1B	C5	S24W61	AR2420
1980 MAY 02	2343	1N		N26E57	AR2423
1980 MAY 05	1932	1F	C3	S26E14	AR2418
1980 MAY 07	2048	SN	C3	S22W16	AR2418
1980 MAY 15	2047	1B	M2	S12E65	AR2456
1980 MAY 16	2233	1B	M2	S14E48	AR2456
1980 MAY 28	1952	1B	X1	S18W35	AR2470
1980 MAY 28	2207	1B	M3	S24W33	AR2470
1980 MAY 28	2344	1B	M7	S16W38	AR2470
1980 JUN 04	2301	1B	X2	S14W69	AR2478
1980 JUN 19	1839	1B	M1	S27E42	AR2522
1980 JUN 24	2003	1B	M1	S23W13	
1980 JUN 29	1824	2B	M4	S25W90	AR2522
1980 JUN 30	1828		M1		AR2544
1980 JUL 01	1628	1B	X2	S12W37	AR2544
1980 JUL 11	1904	2B	X1	S10E72	AR2562
1980 JUL 12	1737	SB	C7	S09E59	AR2562
1980 JUL 12	1828	1B	M2	S12E66	AR2562
1980 JUL 13	1719	SB	M2	S11E46	AR2562
1980 JUL 20	1927	1B	M1	S19W44	AR2562
1980 AUG 23	2129	1B	M2	N16W39	AR2629

VI. REFERENCES

Hurford, G. J., and Tang, F., 1981, B.A.A.S., 13 (in press).

Kundu, M. R., and Alissandrakis, C. E., 1975, M.N.R.A.S., 173, 65.

Marsh, K. A., Hurford, G. J., Zirin, H., Dulk, G. A., Dennis, B. R., Frost, K. J., and Orwig, L. E., 1981, Astrophs. J. (in press).

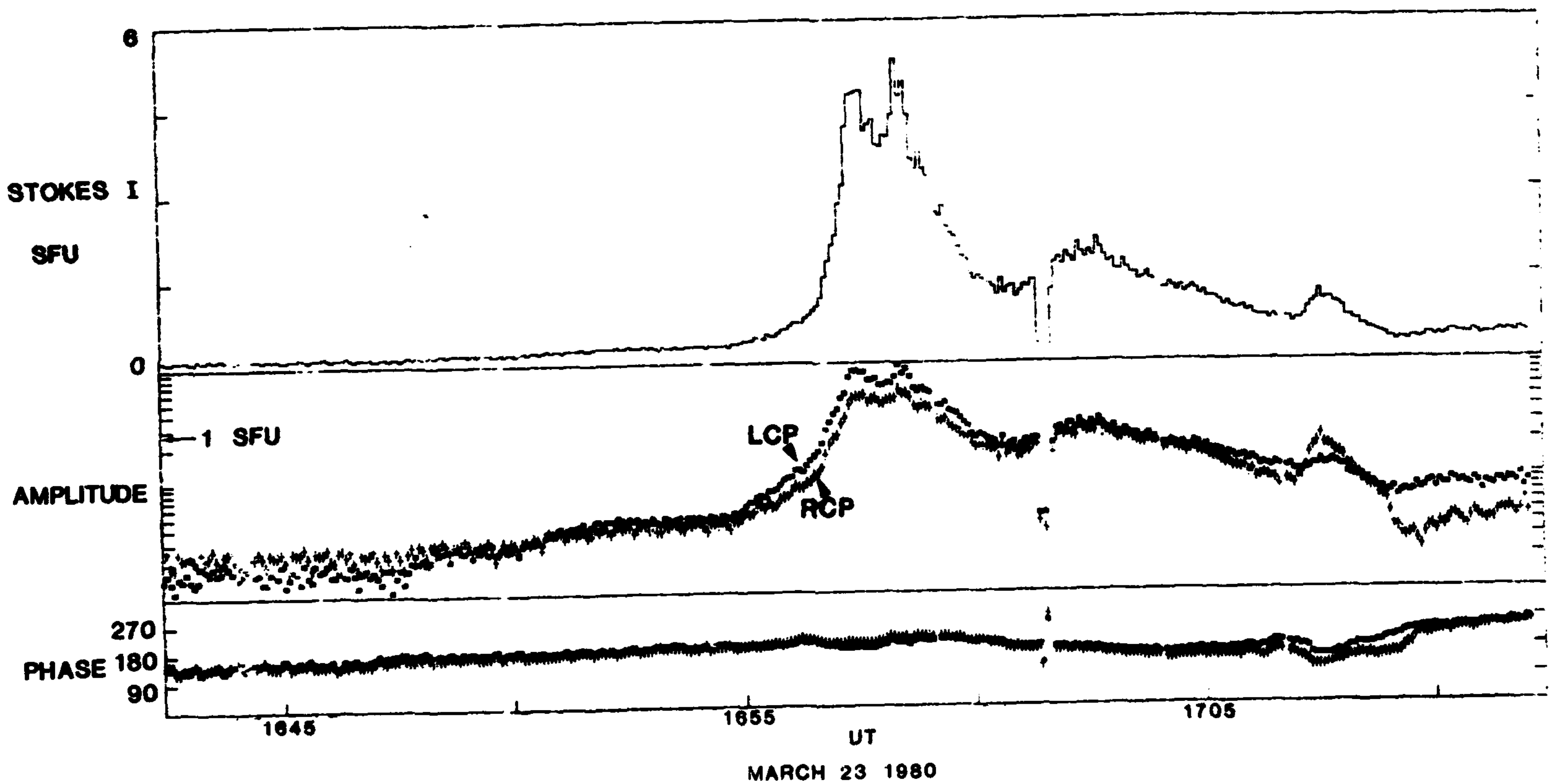
Martin, S. F., 1981, Solar Physics, 68, 217.

van Hoven et al., 1980, Solar Flares (ed P. Sturrock), p 17.

Zirin, H., Hurford, G. J., and Marsh, K. A., 1978, Astrophys. J., 224, 1043.

Zirin, H., and Neidig, D. F., 1981, BBSO, 202, preprint.

Zirin, H., and Tanaka, K., 1981, BBSO, 191, preprint.



6
STOKES I
SFU
0
1 SFU
LCP
RCP
AMPLITUDE
270
180
PHASE
90
1645
1655
1705
UT
MARCH 23 1980

FIGURE 1

3-23-80

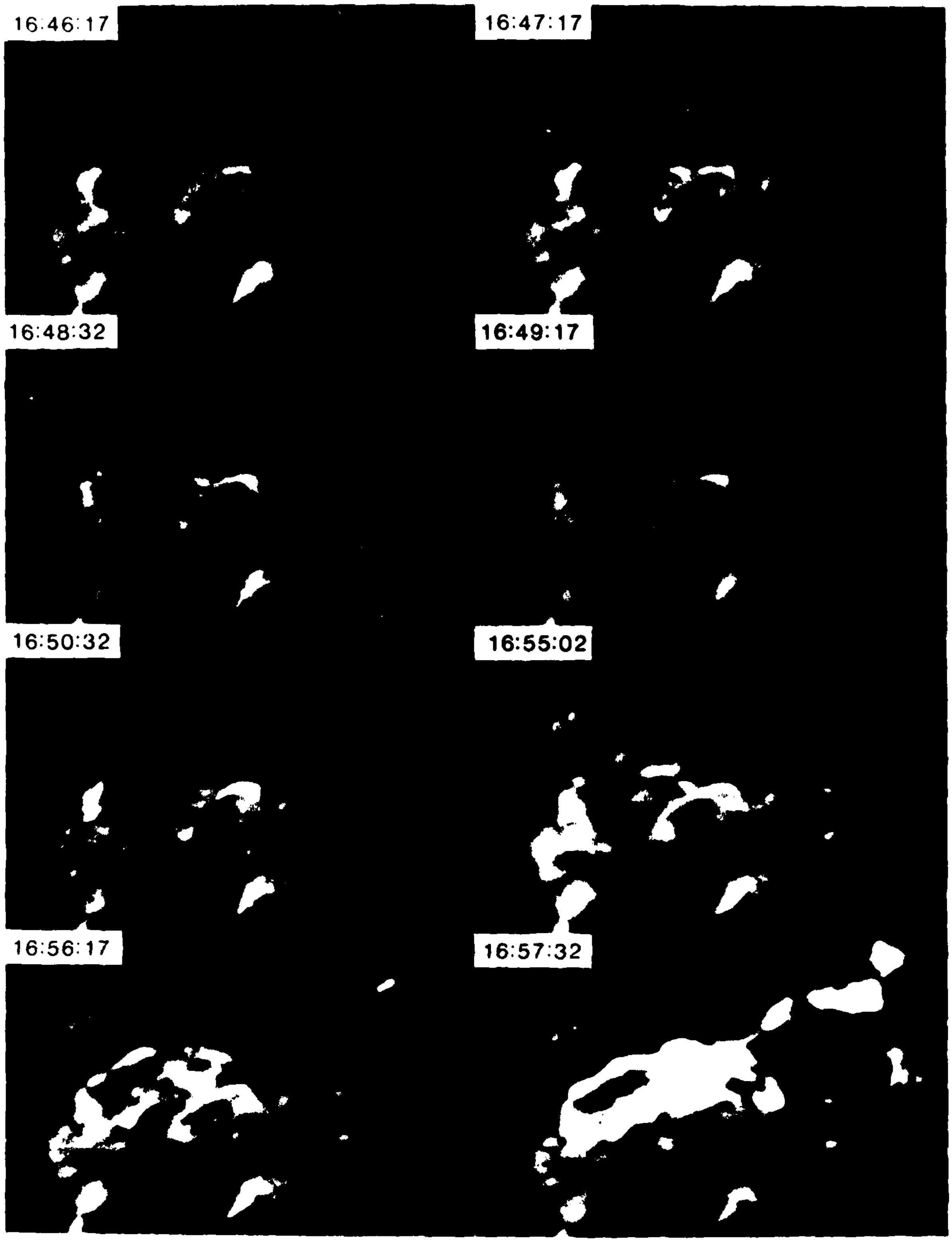


FIGURE 2

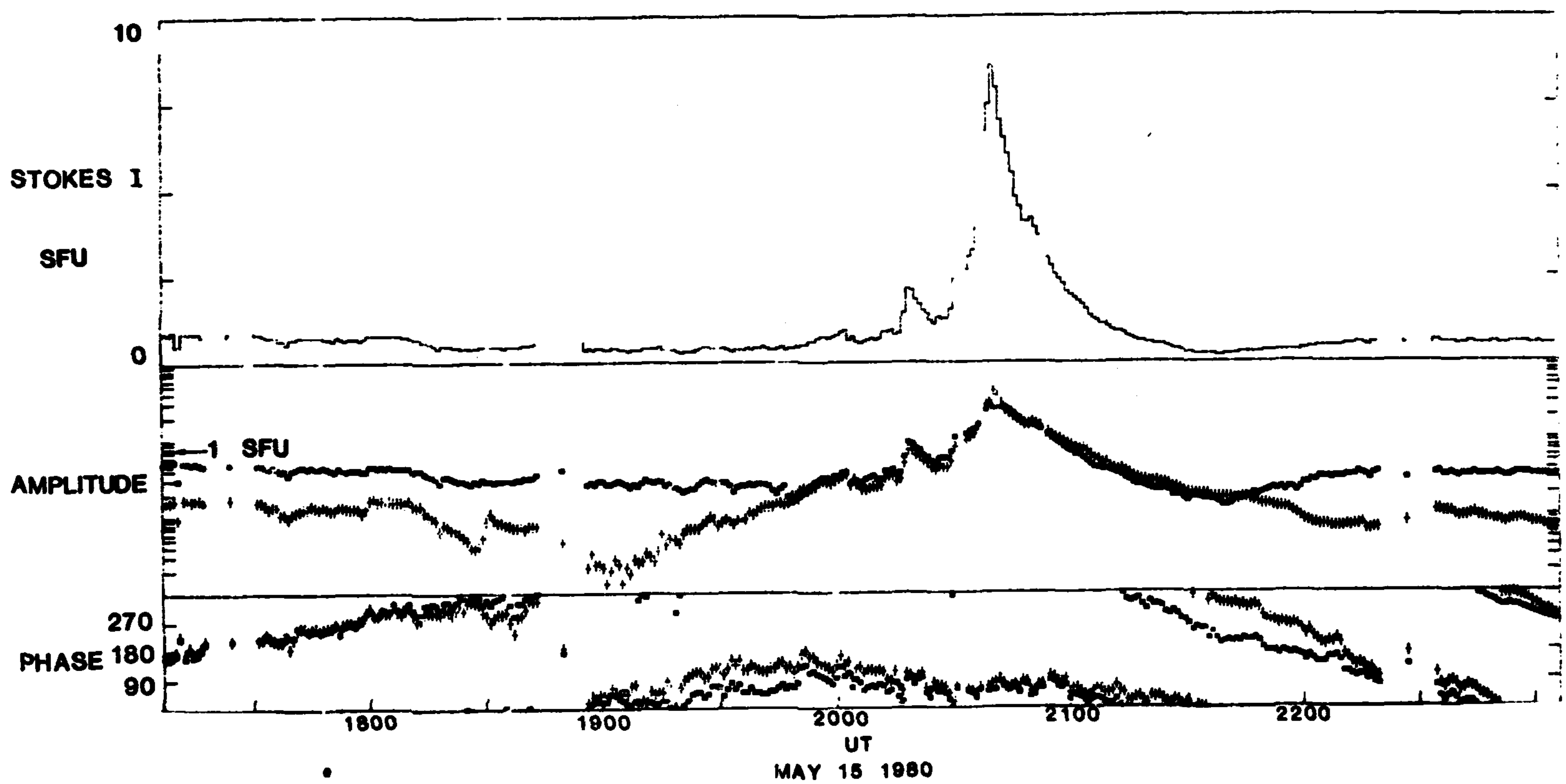

10
STOKES I
SFU
0
1 SFU
AMPLITUDE
270
PHASE 180
90
1800
1900
2000
2100
2200
UT
MAY 15 1980

FIGURE 3

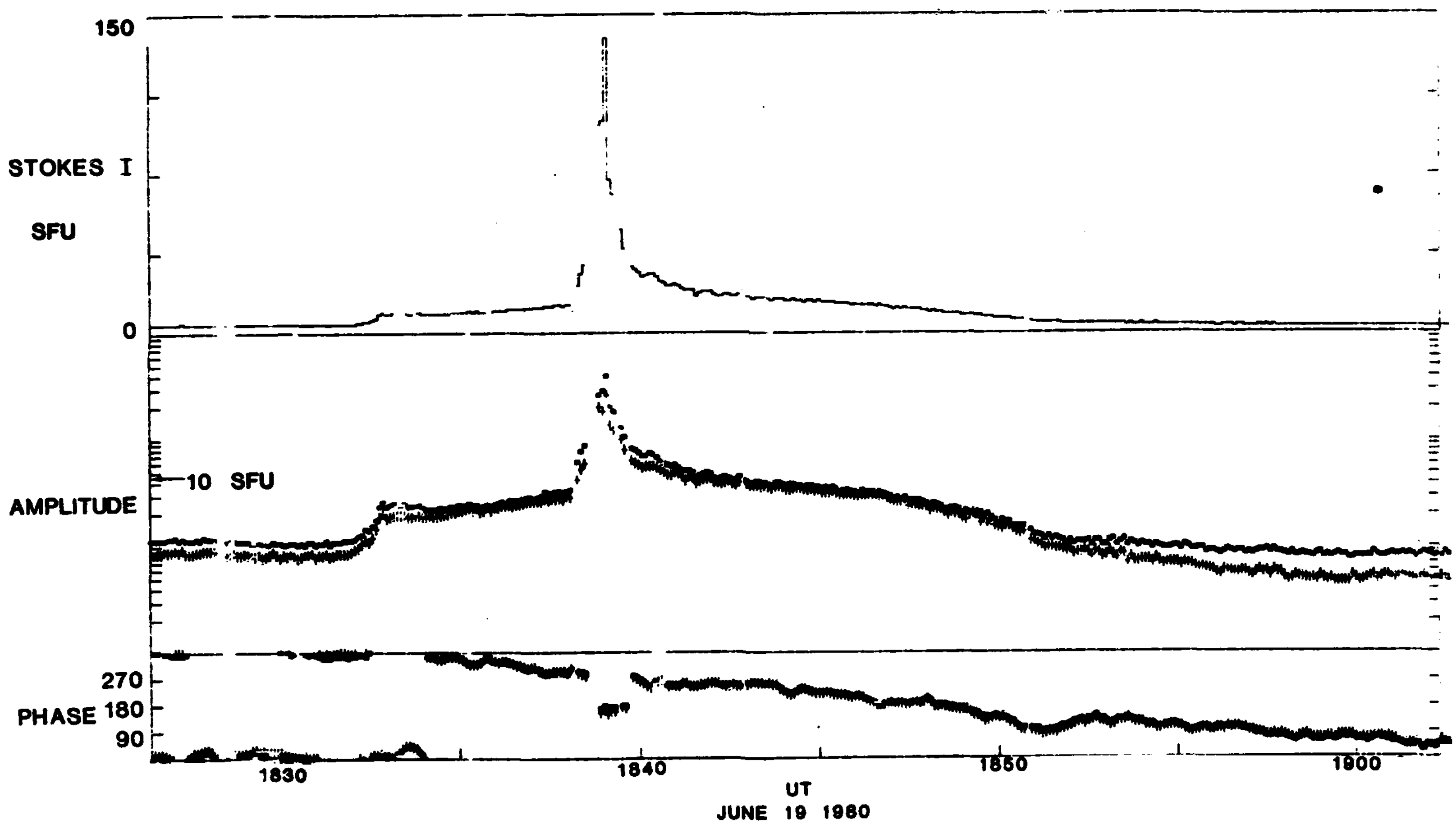

150
STOKES I
SFU
0
10 SFU
AMPLITUDE
270
PHASE 180
90
1830
1840
1850
1900
UT
JUNE 19 1980

FIGURE 4

6-19-80

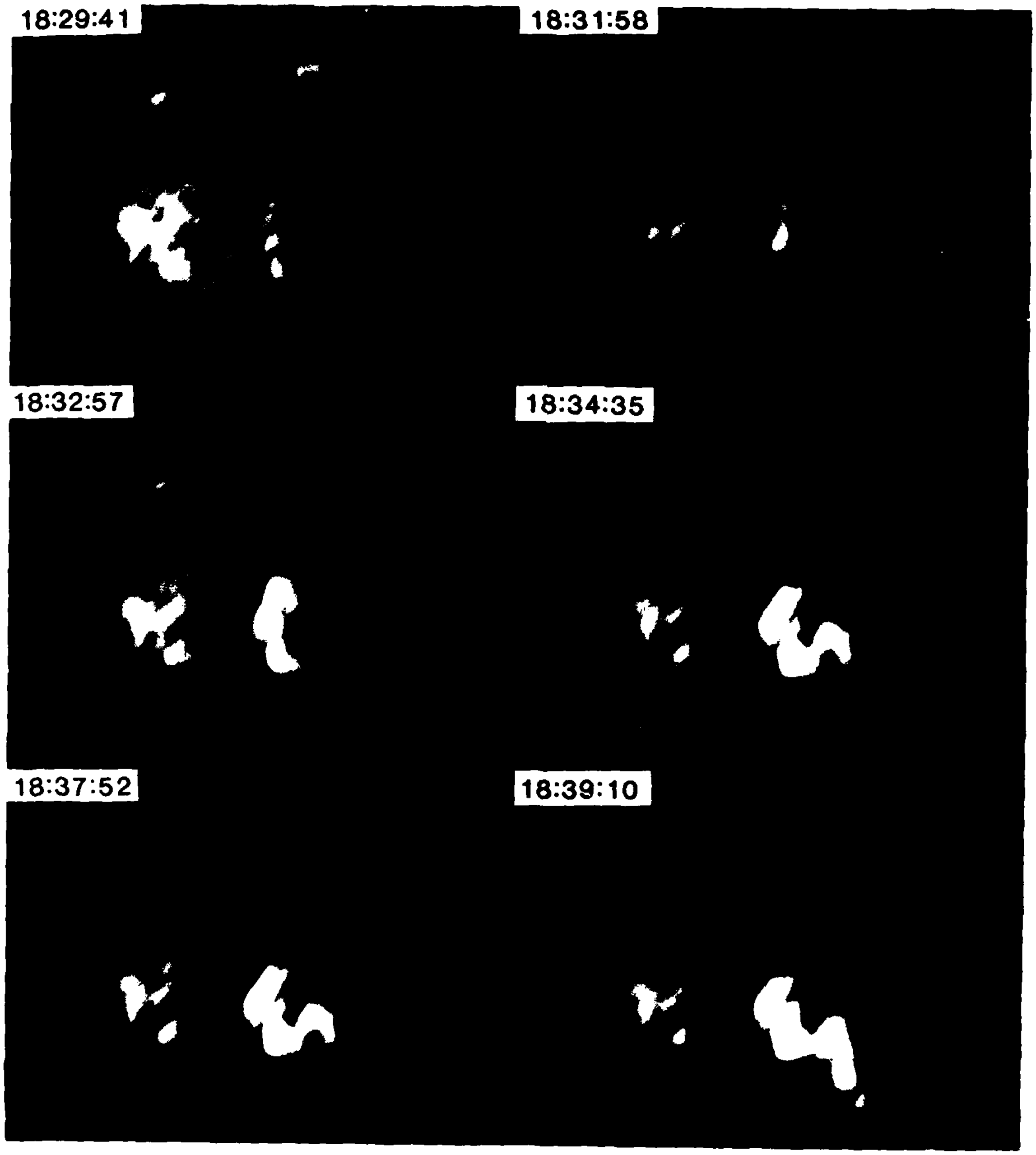


FIGURE 5

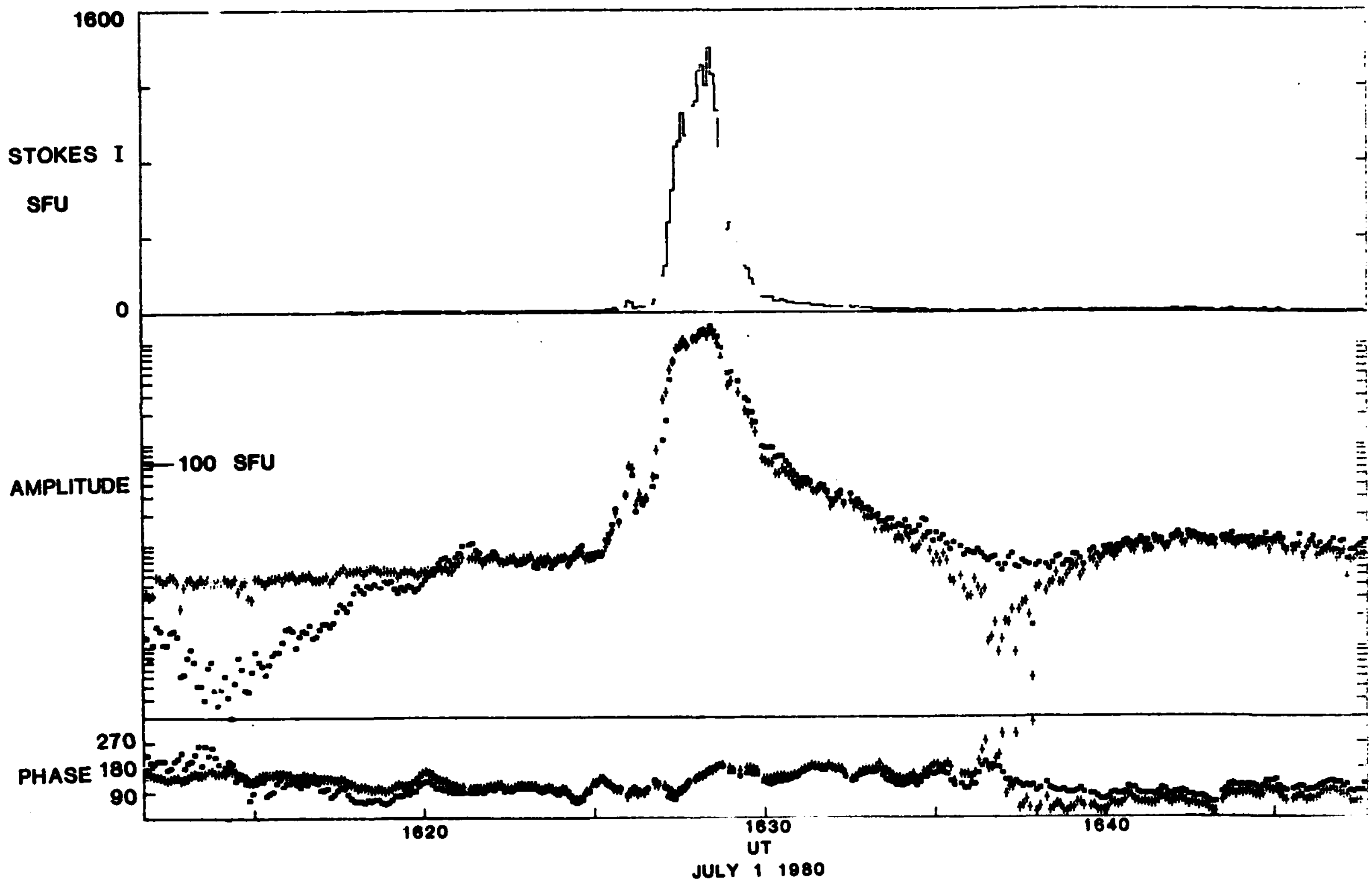

1600
STOKES I
SFU
0
AMPLITUDE
100 SFU
270
PHASE 180
90
1620
1630
UT
JULY 1 1980
1640

FIGURE 6

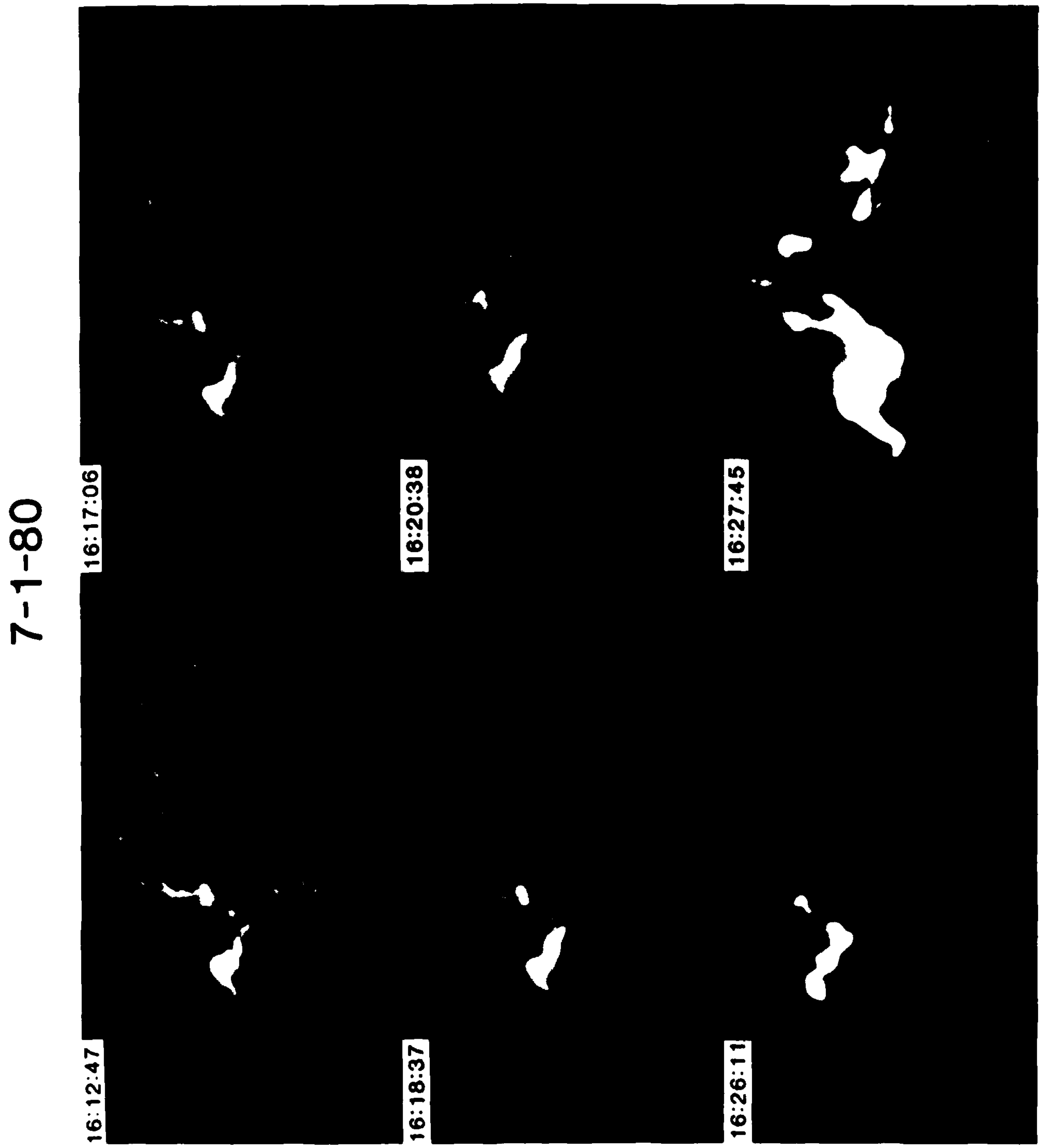
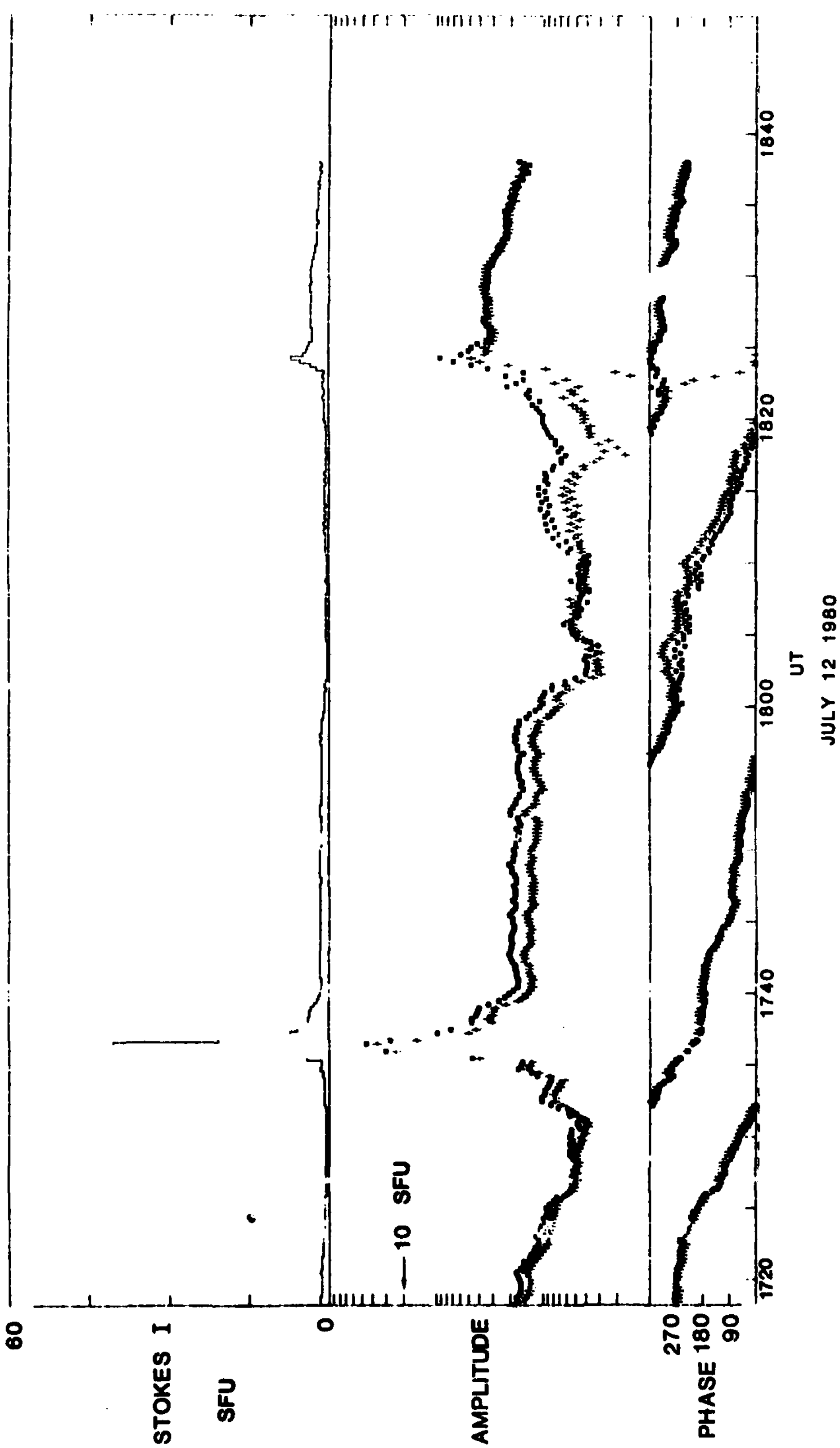
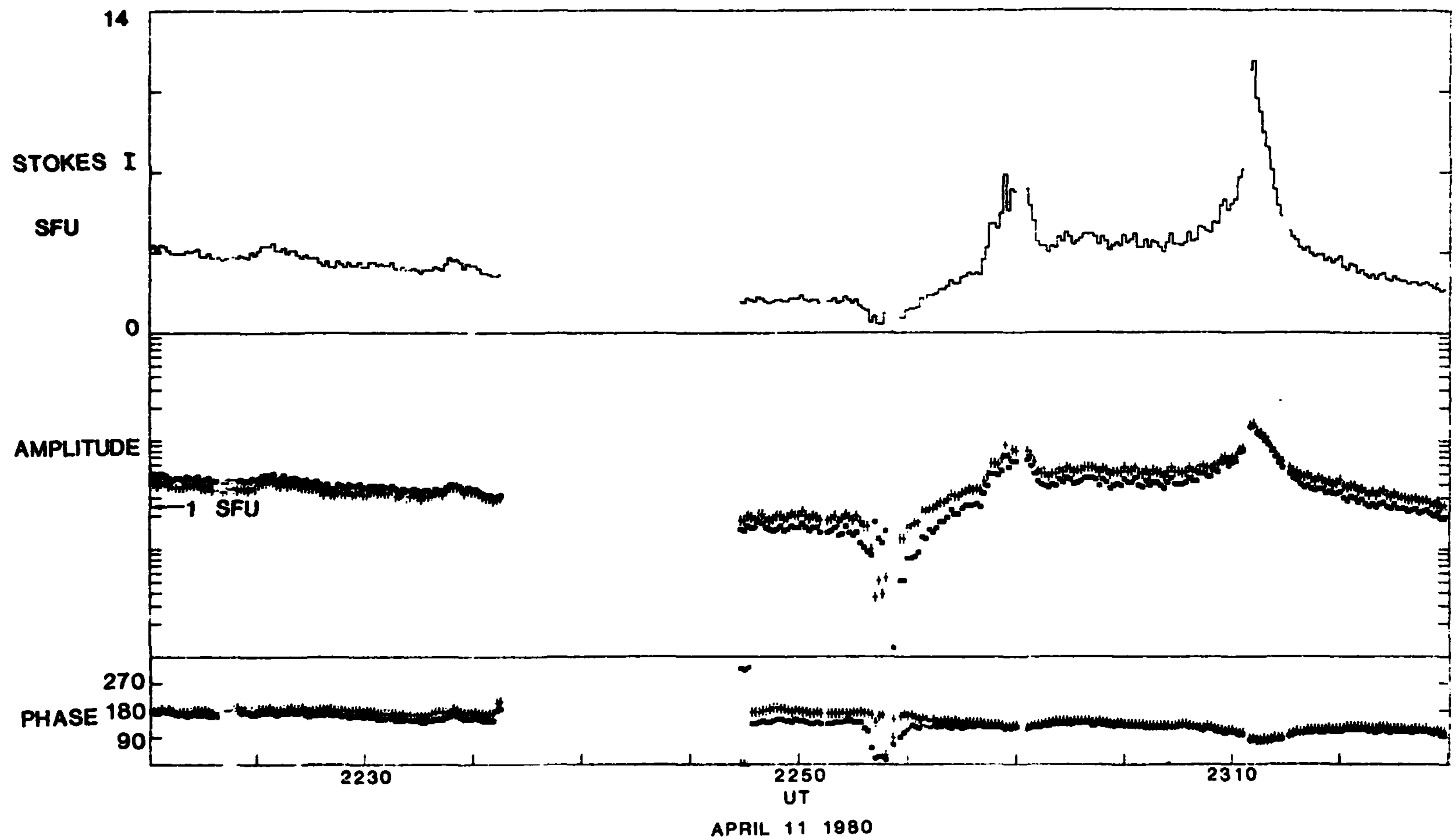


FIGURE 7



STOKES I
SFU
60
0
10 SFU
AMPLITUDE
PHASE
270
180
90
1720
1740
1800
1820
1840
UT
JULY 12 1980

FIGURE 8



14
STOKES I
SFU
0
AMPLITUDE
1 SFU
270
PHASE 180
90
2230
2250
UT
2310
APRIL 11 1980

FIGURE 9

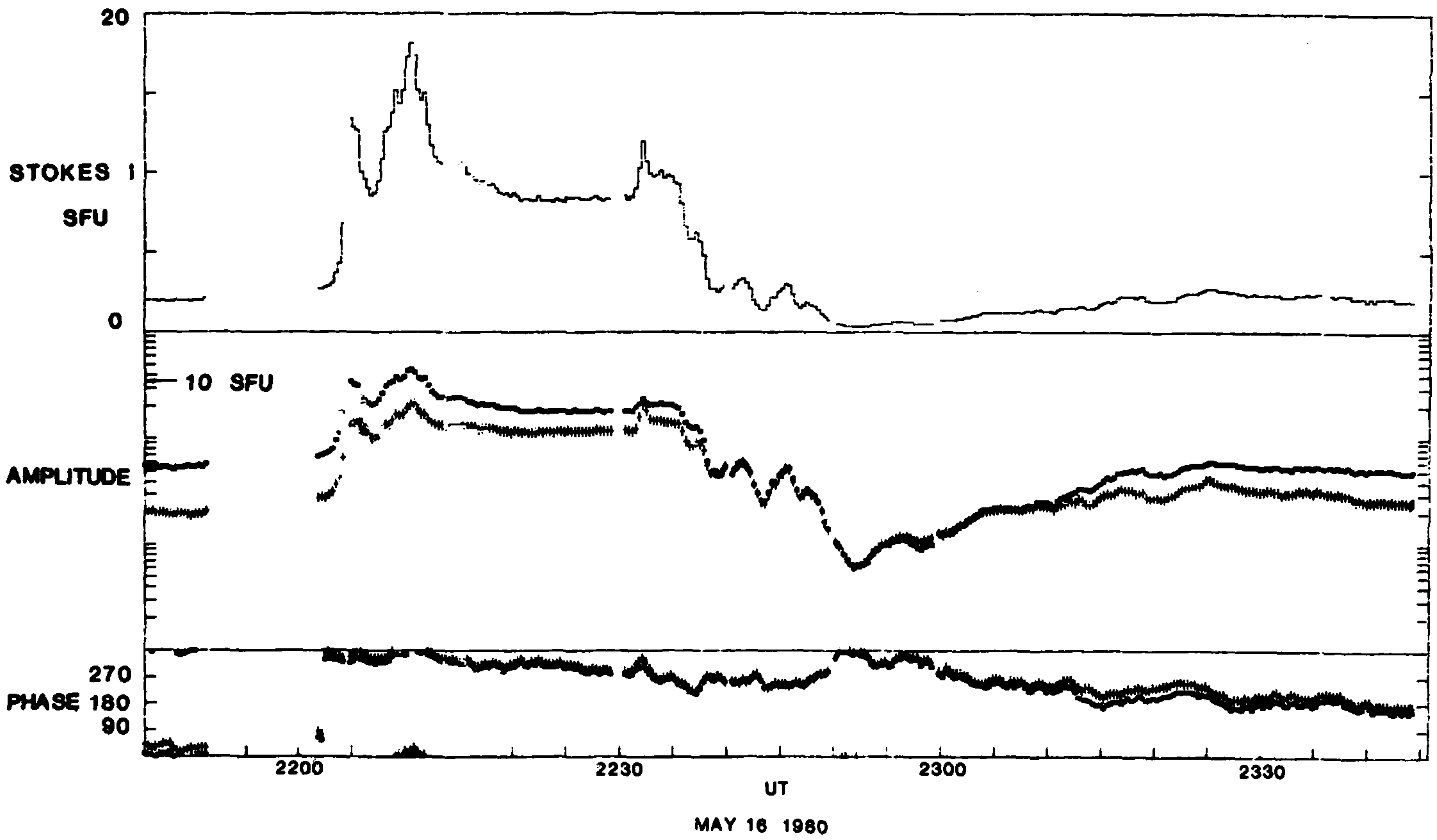

20
STOKES I
SFU
0
10 SFU
AMPLITUDE
270
PHASE 180
90
2200
2230
2300
2330
UT
MAY 16 1980

FIGURE 10

FIGURE CAPTIONS

Figure 1. Microwave time profile for March 23, 1980 event. The top panel shows the amplitude in Stokes I on a linear scale. The center panel shows the RCP and LCP behavior on a logarithmic scale to illustrate the pr impulsive phase changes at 1648 and 1651. The dropout at 1702 is instrumental. The lower panel shows the phase behavior in RCP and LCP.

Figure 2. H-alpha observations of the March 23, 1980 event. Note the disappearance of the upper leg of the dark filament (left center) at between 1647 and 1648, (coincident with the first change in the microwave polarization in Figure 1) and the disintegration of the lower leg by 1650.

Figure 3. Microwave time profile for the May 15, 1980 event. The format is the same as Figure 1. Note the same polarization behavior as in Figure 1, but with a considerably slower timescale.

Figure 4. Microwave time profile for the June 19, 1980 event. The format is the same as Figure 1. The preimpulsive phase step-like increase in amplitude and

decrease in polarization is clear.

Figure 5. H-alpha observations for the June 19, 1980 event. The steplike increase in microwave amplitude at 1832 coincided with a continuing development of a small optical brightening.

Figure 6. Microwave time profile for the July 1, 1980 event. The format is the same as in Figure 1. Note the now-familiar polarization signature at around 1620.

Figure 7. H-alpha observations for the July 1, 1980 event. Note the intensification of the H-alpha brightness in the lower right bright loop at 1620.

Figure 8. Microwave time profiles for the two major flares on July 12, 1980. The format is the same as Figure 1. Note the amplitude decreases before the impulsive phase. (See text for a discussion of their possible significance.)

Figure 9. Microwave time profile leading up to the major flare at 2311 on April 11, 1980. The format is the same as in Figure 1. Note the polarization reversal during the

calibration gap at 2240 and the failure of the microwave amplitude to return to its previous level after the smaller event at 2259.

Figure 10. Microwave time profile leading up to the major flare at 2232 on May 16, 1980. The format is the same as in Figure 1. Note the failure of the microwave amplitude to return to its previous level after the smaller events (in soft X-rays) at 2205 and 2210.