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Hard X-Ray Highlights of AR 5395

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Active Region 5395 produced an exceptional series of hard X-ray bursts notable for their frequency, intensity, and impulsivity. Over the two weeks from March 6-19, 447 hard X-ray flares were observed by the Hard X-Ray Burst Spectrometer on Solar Maximum Mission (HXRBS/SMM), a rate of ~35 per day which exceeded the previous high by more than 50% (figure 1). During one 5 day stretch, more than 250 flares were detected, also a new high. The three largest GOES X-flares were observed by HXRBS and had hard X-ray rates over 100,000 s^{-1} (figure 2) compared with only ten flares above 100,000 s^{-1} during the previous nine years of the mission.

Throughout the entire two weeks many of the flares showed extreme impulsivity, some events with a collection of fast spikes and others showing a single rapid intense spike. One form of impulsivity was exhibited by the M2 flare of 1989 March 7 (figure 3), which is the most intense single spike event measured by HXRBS. The flare starts in hard X-rays close to 557 UT and begins a steady exponential rise (e-folding time ~3.7 s) to a peak above 40,000 s^{-1} at 557:45 UT. Subsequently, the event decays rapidly to a small fraction of its peak within 30 s. Such events are usually thought to show the rapid acceleration of particles, fast release of flare energy, and the probable injection of energetic electrons into a dense cooler medium where the X-rays are produced. Another variety of impulsive flare is illustrated by the fast event on 1989 March 13 starting close to 1225 UT (figure 4). After 10-20 s of weak activity there are two consecutive hard X-ray spikes which each rise and fall within a second. Fast spikes have been seen before but these are more intense than most such events.

An ongoing effort for the HXRBS group has been the correlated analysis of hard X-ray data with flare data at other wavelengths with the most recent emphasis on those measurements with spatial information. During a series of bursts from AR5395 at 1644-1648 UT on 12 March 1989, simultaneous observations were made by HXRBS and UVSP (Ultra Violet Spectrometer Polarimeter) on SMM, the two-element Owens Valley Radio Observatory (OVRO) interferometric array, and R. Canfield's Hα Echelle spectrograph at the National Solar Observatory at Sacramento Peak. The data in figures (5) and (6) show strong correlations in the hard X-ray, microwave, and uv lightcurves. This event will be the subject of a combined analysis.

The UVSP data (figure 6) from this same flare are an example from a continuing study with HXRBS. Previous studies by SMM of bursts in hard X-rays and ultraviolet (UV) have shown a close temporal and spatial relationship between the fast spikes in both wavebands (Orwig and Woodgate 1986, Poland et al. 1982). In fact, to within instrumental resolution of ~.1 s, there is frequently no discernible delay between peaks in the hard X-rays and the UV. Within the context of thick-target X-ray emission, this near simultaneity suggests that the UV is produced very close to the fast-electron energy loss region. The emitting regions would be virtually cospatial assuming that the UV is produced within the transition zone or separated by no more than a couple of arcseconds assuming fluorescence from the temperature minimum immediately below.

The UVSP data (figure 6) are obtained at a wavelength of ~λ1375 A and consist of the time histories from a 3 x 3 array of 10 arcsecond pixels, sampled every 1.2 s (56 ms dwell time per pixel), centered on a previously identified UV bright point. Four (bottom right and the three on the left) of the nine pixels show common fast structures clearly identifiable within the hard X-ray light curve. These fast structures are simultaneous within the 1.2 s cycle implying a minimum propagation velocity of at least 8000 km/sec between the corner pixels (14"x750 km/ 1.2 s). In figure (7) the HXRBS data and the UVSP data from pixel 02 (lower left in figure (6)) reveal several simultaneous temporal features. Depending on the spatial structure revealed at other wavelengths, these data could provide strong evidence of foot-point electron energy loss.

Orwig, L.E. and Woodgate, B.E.: 1986, in "The Lower Atmosphere in Solar Flares", 306-317.
Poland, A.I. et al.: 1982, Solar Phys. **78**, 201.

Figure Captions

1. HXRBS event rate for two week intervals over the entire mission. The peak at 27 events/day was during the passage of AR5395 across the disk.

2. All of the HXRBS events with a peak rate greater than 10,000 counts/s with the events over 100,000 counts/s specially noted. The three largest GOES-class X flares from AR5395 all occurred during spacecraft day and each produced in excess of 100,000 counts/s.

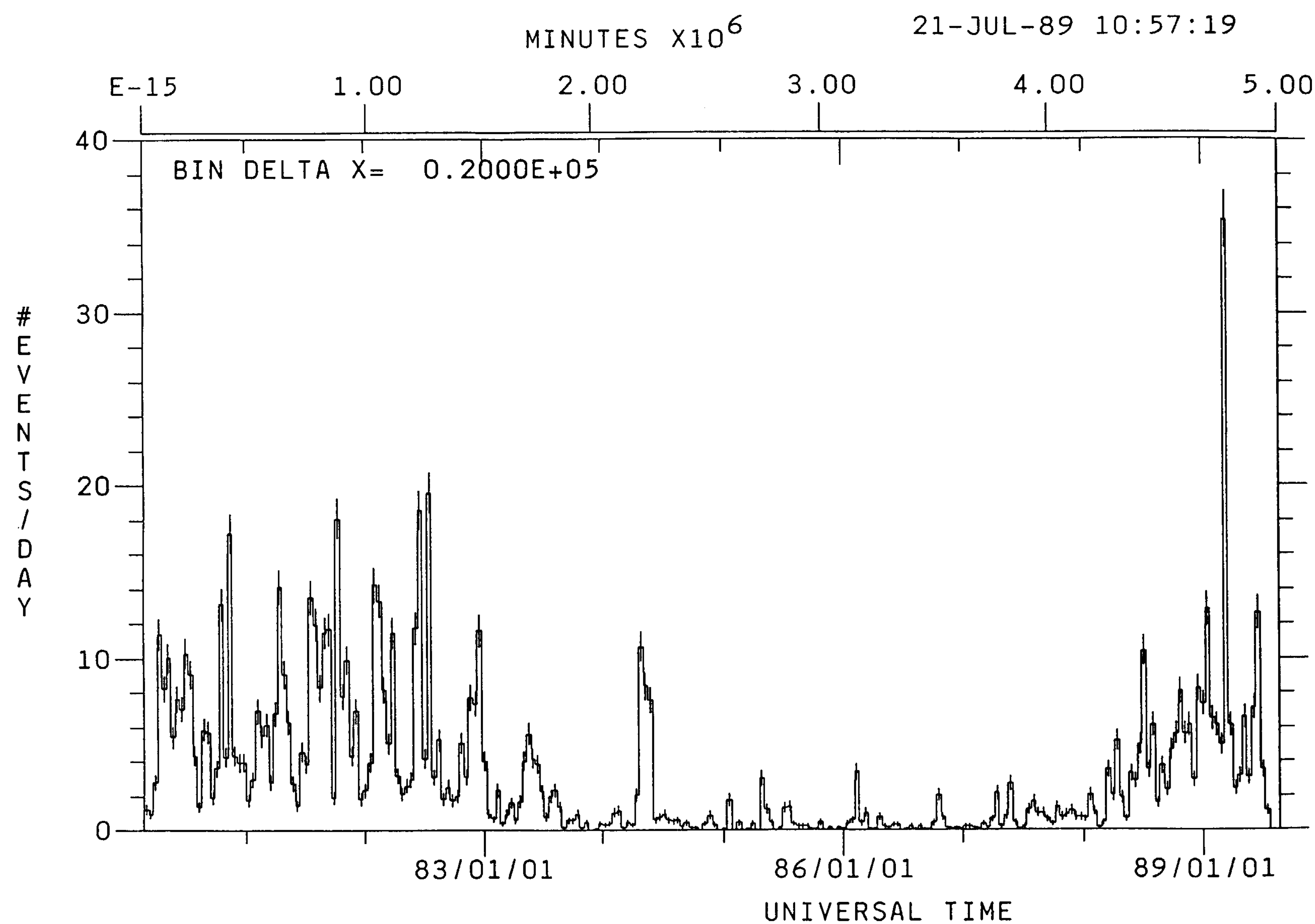
3. The most intense single spike event seen by HXRBS during the mission rising two orders of magnitude in 15 seconds to a peak of over 40,000 counts/sec.

4. Two fast consecutive spikes seen by HXRBS from AR5395. Both spikes rise and fall in about 1s and are unusually intense to have such fast time constants.

5. The integrated hard X-ray flux and multiband microwave data from the flare on 12 March 1989 at 1646 UT from AR5395 seen by HXRBS and the OVRO 2-element array.

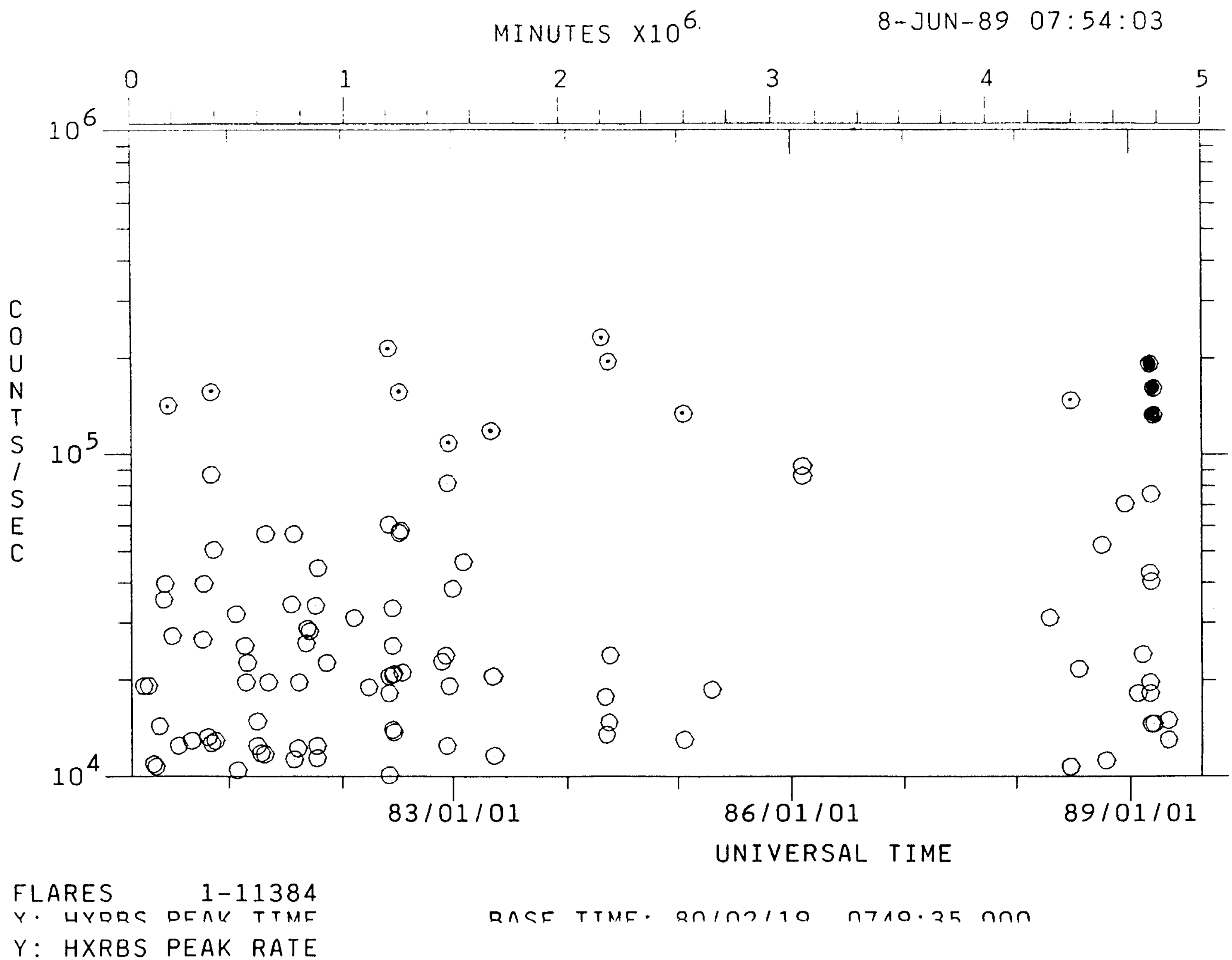
6. The light curves from the UVSP 3x3 raster. (10x10 arcsecond pixels spaced by 10 arcsecond with a 1.2 s cycle time) Four (bottom right and the three on the left) of the nine pixels show fast structure clearly identifiable with the hard X-ray light curve and amongst themselves.

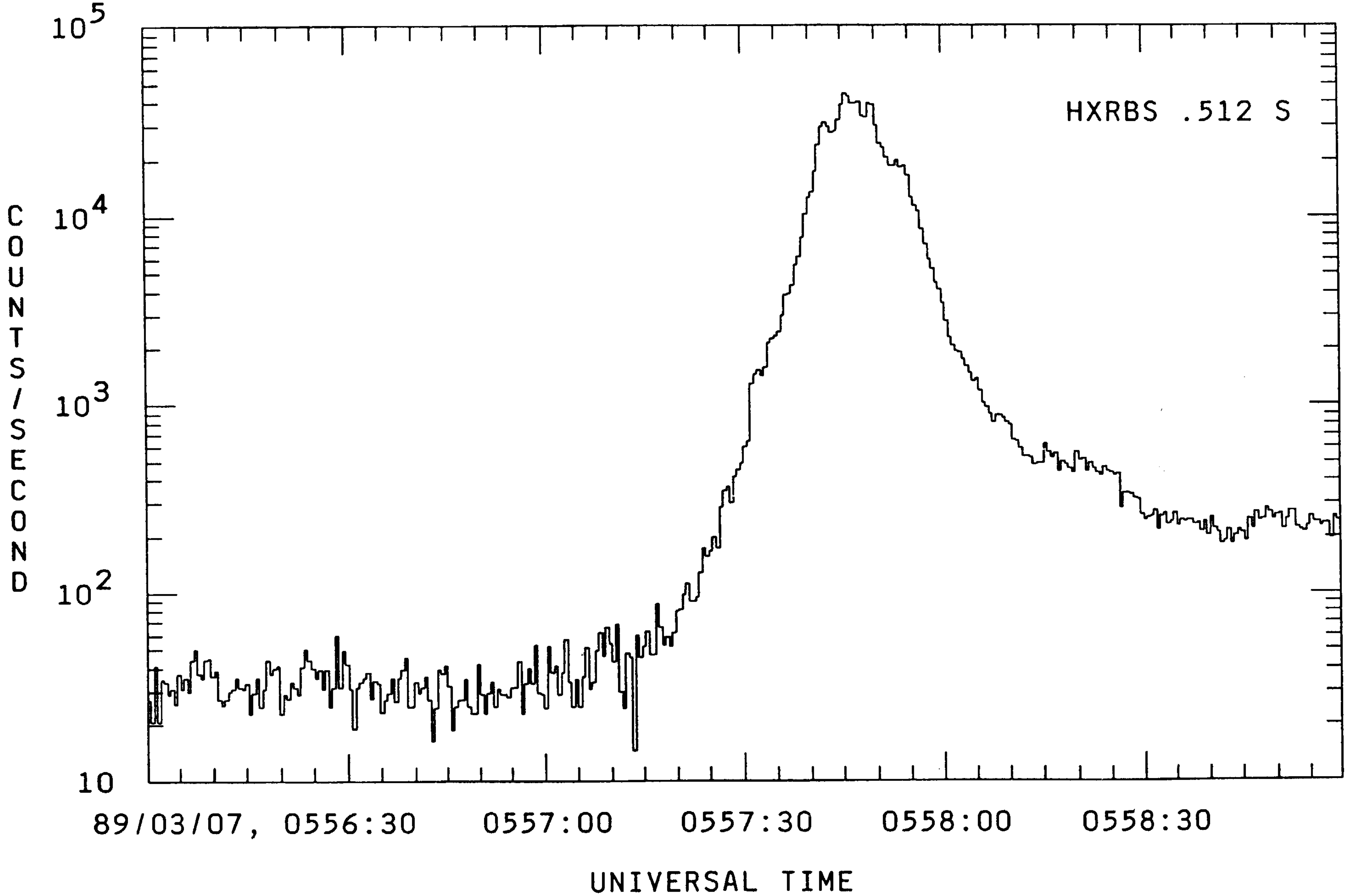
7. The same flare as in figures (5) and (6) illustrating the correspondence between the UV and hard X-ray structures for a single pixel from the raster. Here we have identified at least 5 common features simultaneous between the two within the cycle time limitation imposed by the raster.



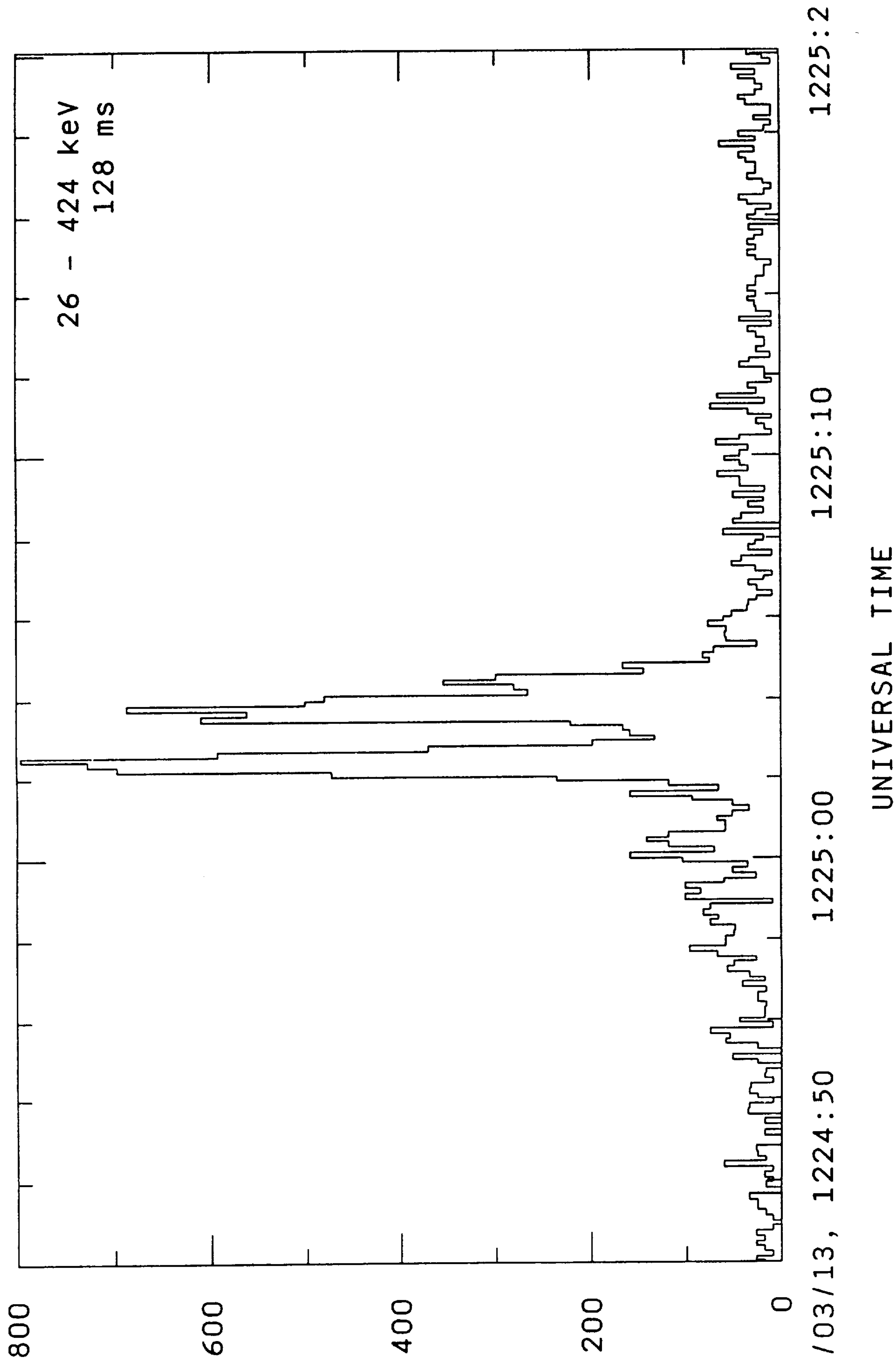
FLARES 1-11694
X: HXRBS PEAK TIME
Y: DOWN TIME INCLUDED

BASE TIME: 80/02/15, 0000:00.000

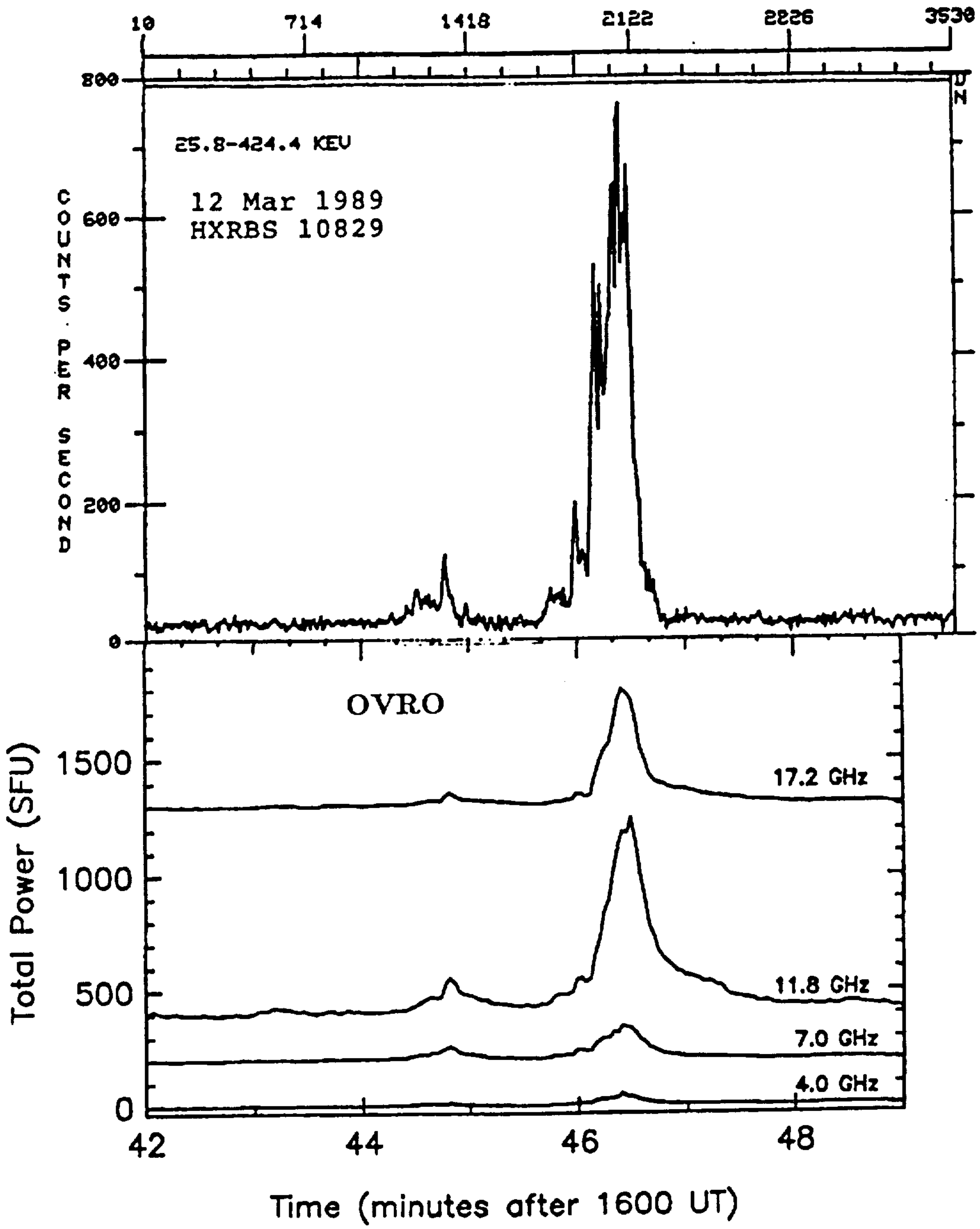

8-JUN-89 07:54:03
MINUTES X10^6
0
1
2
3
4
5
10^6
10^5
10^4
COUNTS/SEC
83/01/01
86/01/01
89/01/01
UNIVERSAL TIME
FLARES 1-11384
Y: HXRBS PEAK TIME
BASE TIME: 80/02/19 0748:35.000
Y: HXRBS PEAK RATE

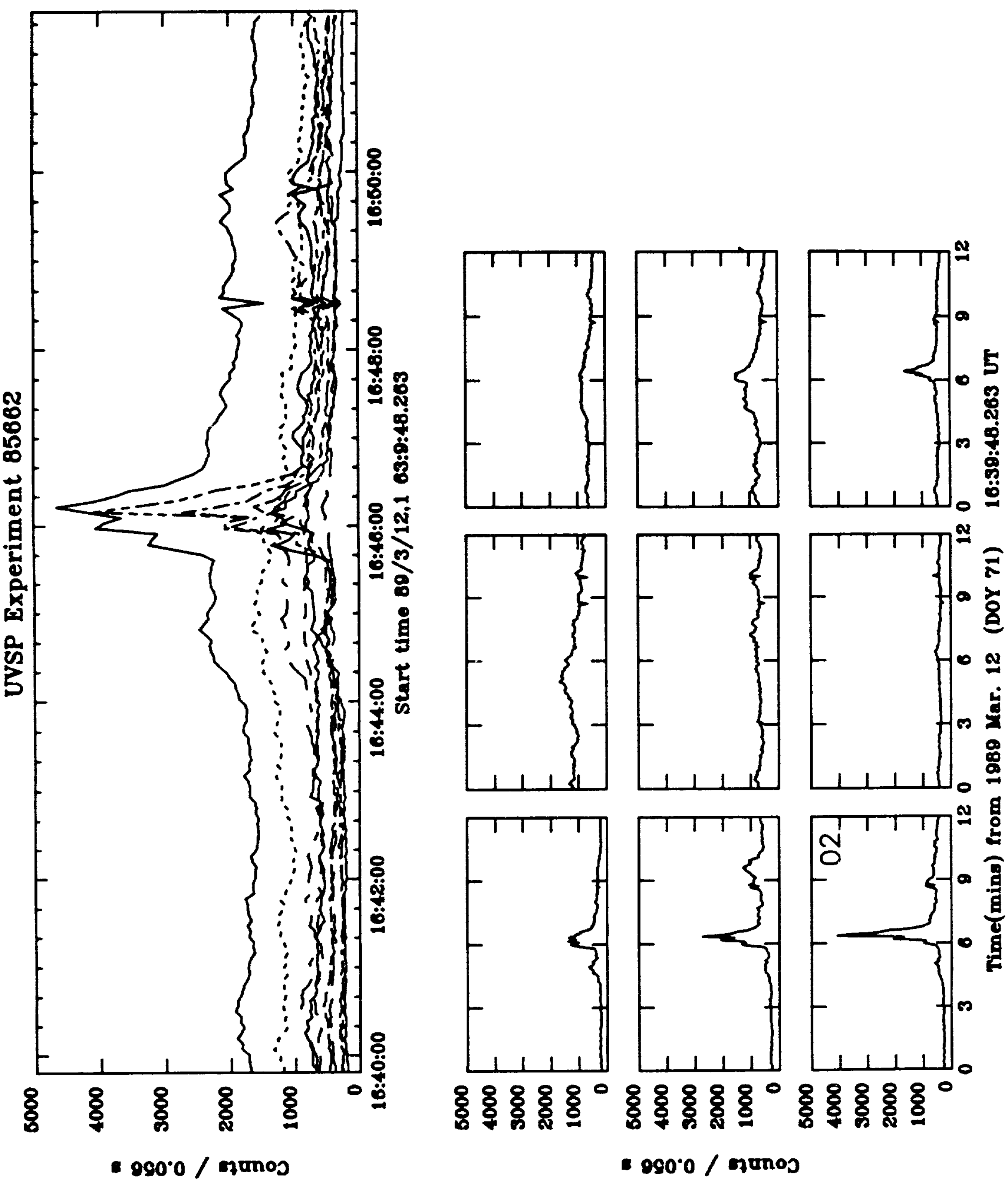


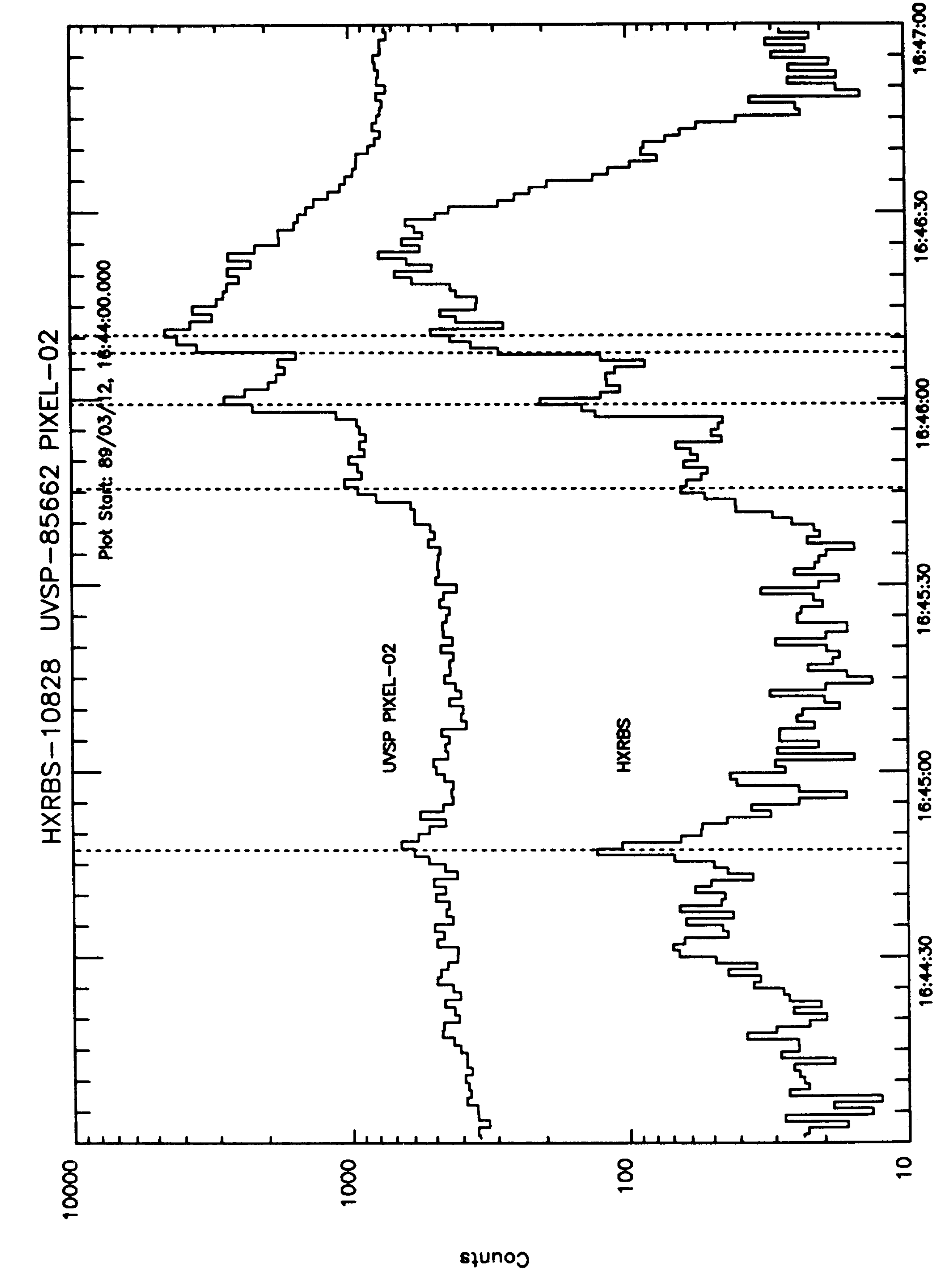
HXRBS .512 S
COUNTS/SECOND
10^5
10^4
10^3
10^2
10
89/03/07, 0556:30
0557:00
0557:30
0558:00
0558:30
UNIVERSAL TIME



26 - 424 keV
128 ms
COUNTS/SECOND
800
600
400
200
0
89/03/13, 1224:50
0
1225:00
1225:10
1225:2
UNIVERSAL TIME


10
714
1418
2122
2826
3530
25.8-424.4 KEV
12 Mar 1989
HXRBS 10829
COUNTS PER SECOND
800
600
400
200
0
OVRO
Total Power (SFU)
1500
1000
500
0
17.2 GHz
11.8 GHz
7.0 GHz
4.0 GHz
42
44
46
48
Time (minutes after 1600 UT)


UVSP Experiment 85662
Counts / 0.056 s
Start time 89/3/12,1 63:9:46.263
16:40:00
16:42:00
16:44:00
16:46:00
16:48:00
16:50:00
Counts / 0.056 s
Time(mins) from 1989 Mar. 12 (DOY 71)
16:39:46.263 UT
02


HXRBS-10828 UVSP-85662 PIXEL-02
Plot Start: 89/03/12, 16:44:00.000
UVSP PIXEL-02
HXRBS
Counts
10000
1000
100
10
16:44:30
16:45:00
16:45:30
16:46:00
16:46:30
16:47:00

ORIGINAL PAGE IS
OF POOR QUALITY

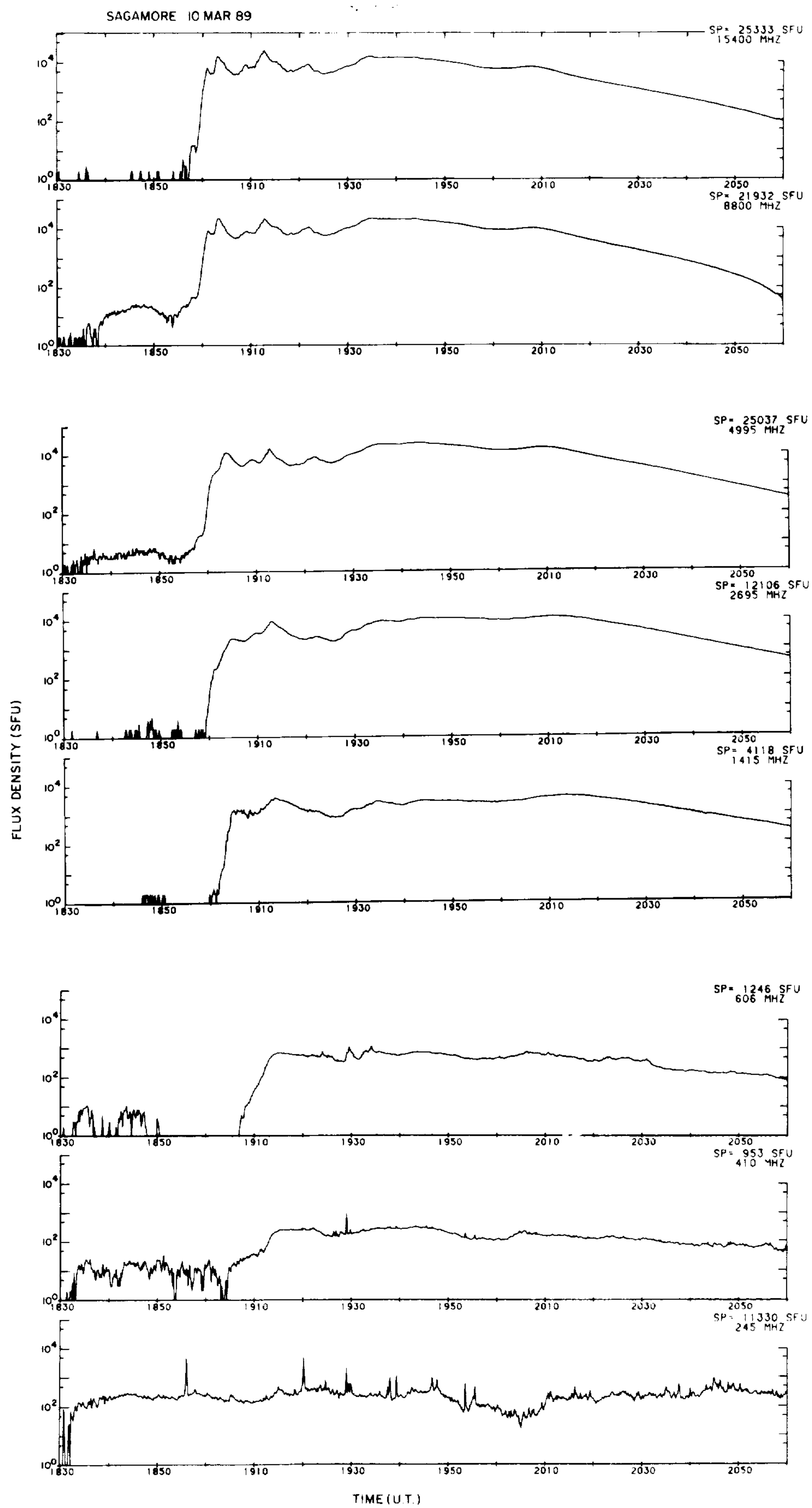


Fig. 2 Sagamore Hill observations of the large microwave burst on 10 March 1989.