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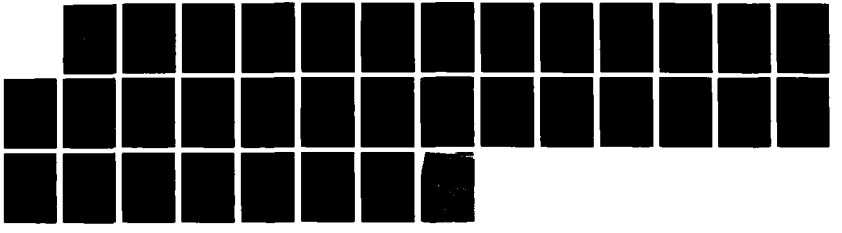

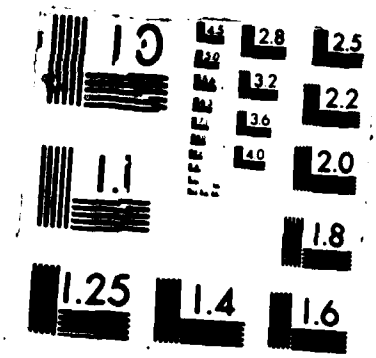
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INTERPLANETARY PROTON ($0.61 < E_p < 3.41$ MeV) EVENTS OBSERVED WITH PIONEER 11, 1973-1986 AND OUT TO 22.4 AU

by

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U. of Iowa 87-22

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER U. of Iowa 87-22	2. GOVT ACCESSION NO. ADA182955	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Interplanetary Proton ($0.61 < E_p < 3.41$ MeV) Events Observed with Pioneer 11, 1973-1986 and Out to 22.4 AU		5. TYPE OF REPORT & PERIOD COVERED Progress, July 1987 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) JAMES A. VAN ALLEN		8. CONTRACT OR GRANT NUMBER(s) N00014-85-K-0404
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Physics and Astronomy The University of Iowa Iowa City, Iowa 52242		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Electronics Program Office Arlington, VA 22217		12. REPORT DATE July 1987 13. NUMBER OF PAGES 31
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 is unlimited.

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

18. SUPPLEMENTARY NOTES

Submitted for publication to Solar Physics.

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

Solar Protons
Interplanetary Proton Events
Heliosphere

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

See page following.

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ABSTRACT

A survey of interplanetary proton ($0.61 < E_p < 3.41$ MeV) events is summarized in graphical and tabular form for the period April 1973 through December 1986. The observations were obtained by an effectively continuous data stream from the University of Iowa instrument on the Ames Research Center/NASA spacecraft Pioneer 11 as it moved outwards in the solar system from 1.0 to 22.4 AU. Two hundred and sixty-five distinct events are identified. The spectra and intensities of the protons, presumed to be originally of solar origin, are influenced dramatically by propagative and accelerative processes in the interplanetary medium.

1. Introduction

The interplanetary intensity of low energy protons ($0.61 < E_p < 3.41$ MeV) has been observed on an effectively continuous basis by the University of Iowa instrument on the Ames Research Center/National Aeronautics and Space Administration spacecraft Pioneer 11 [Fimmel et al., 1980] since its launch on 6 April 1973. A catalog of 265 distinct events of enhanced intensity has been compiled for the period through 1986, a period spanning solar sunspot cycle 21 and including the solar field reversal in mid-1980 [DeVore and Sheeley, 1987]. During this period Pioneer 11 moved outward in the solar system from 1.0 to 22.4 AU (including close encounters with Jupiter and, for the first time, with Saturn). An overview of this survey is presented in graphical and tabular form in order to provide a basis for correlative and interpretative work. The survey data are given as daily means. Much finer detail can be made available to interested collaborators.

2. The Detector

The sensitive element of the detector (Detector G) is a circular disc of totally depleted surface barrier-silicon, $2.87\ (\pm\ 0.02) \times 10^{-3}$ cm in thickness and $0.122\ (\pm\ 0.002)$ cm^2 in frontal area. The directionality of the detector for low energy protons is provided by physical shielding. Its reciprocal unidirectional geometric factor is $22.7\ (\text{cm}^2\ \text{sr})^{-1}$. The experimentally determined energy window for protons is $0.61 < E_p < 3.41$ MeV and the corresponding (calculated) energy window for alpha particles is $0.88 < E_\alpha \lesssim 66$ MeV. The detecting system is unable to distinguish between protons, alpha particles, and heavier nuclei. The counting rate is interpreted as a "proton-equivalent" intensity. The detector is almost completely insensitive to electrons of any energy, even at the high intensities present in the inner radiation belts of Jupiter and Saturn, though it has a slight sensitivity to high energy ($E_p > 41$ MeV) protons passing transversely through the shield more-or-less parallel to the flat face of the disc-shaped element. Further details are given by Van Allen et al. [1980].

A weak Am^{241} alpha particle (5.49 and 5.44 MeV) emitter is provided for end-to-end monitoring of in-flight performance of the detector and the associated electronics. The mean life of Am^{241} is 661 years. Hence, during fourteen years the specific activity decreases by 2 percent. The in-flight "background" rate during extended periods of minimal proton activity has been in the range 0.067 to 0.062 counts s^{-1}. The latter rate (during the exceptionally quiet period of early 1987) has been adopted as that attributable to the calibration source (and to a very minor contribution by galactic cosmic rays). In the present paper the absolute, spin-averaged unidirectional intensity j of protons has been calculated from the counting rate N by the formula

$$j = 22.7\ (N - 0.062)$$

where N is in counts s^{-1} and j is in $(cm^2\ s\ sr)^{-1}$.

3. Telemetry and Angular Distributions

The axis of the cylindrical collimator of the detector is fixed perpendicular to the spacecraft's rotational axis. The latter has been directed continuously toward the earth to an accuracy of 1° throughout the mission. During the 1973-1986 period the rotational period has decreased from 12.5 to 7.3 s.

The telemetry and sampling scheme is described in Van Allen et al. [1980]. Useful angular distributions can be obtained when the telemetry bit rate of the spacecraft equals or exceeds 64 b.p.s., corresponding to an accumulation time of 3.0 s per sample. This telemetry situation has been maintained during most of the mission until mid-1984. During early 1987 the bit rate has been reduced, typically, to 16 b.p.s. At this bit rate individual samples of Detector G data span 12.0 s or about 590° of spacecraft rotation and no useful angular distributions are obtained.

Data from Detector G are accumulated for 18.2 percent of each telemetry cycle, or for 15,709 seconds during 24 hours of continuous telemetry coverage. Daily telemetry coverage during the period of this survey has varied from nearly 100 percent to about 20 percent. For a typical coverage of 40 percent a daily

mean rate of 0.100 counts s^{-1} has a statistical standard error of 0.004 counts s^{-1}. There are very few 24-hour periods during which no observations were obtained; hence, there is a correspondingly small probability that events (usually of several days' duration) were missed.

4. Graphs and Table of Data

For survey purposes, the raw daily mean counting rates (background not subtracted) of Detector G are plotted as a function of time on fourteen annual graphs (Figures 1-14).

In the construction of Table I a threshold counting rate of 0.10 counts s^{-1} was adopted as defining an "active day". The corresponding absolute intensity threshold is 0.9 $(cm^2\ s\ sr)^{-1}$. Under this criterion 265 events (relative peaks of daily mean intensity) were identified in the period April 1973 through Decmber 1986. Table I gives data for these events as well as the positional coordinates r, λ, and β of the spacecraft at the times of selected events. These coordinates are, respectively, radial distance in astronomical units, longitude, and latitude -- all referenced to the heliocentric ecliptic-equinox coordinate system of 1950.0. The observations are organized according to Earth Received Time (ERT) of the data.

5. Previous Interpretative Work

The bibliography includes three previous papers [Pesses et al., 1978, 1979, 1984] that used early portions of the Pioneer 11 data set described herein and that illustrate the interpretative potential of the full data set.

6. Acknowledgments

This work was supported in part by the Ames Research Center/NASA contract NAS2-12327 and in part by the U. S. Office of Naval Research contract N00014-85-K-0404.

References

DeVore, C. R., and N. R. Sheeley, Jr., Simulations of the sun's polar magnetic fields during sunspot cycle 21, Solar Phys. **108**, 47-59, 1987.

Fimmell, R. O., J. Van Allen, and E. Burgess, Pioneer: First to Jupiter, Saturn and Beyond, NASA SP-446, National Aeronautics and Space Administration, Washington, DC, 1980.

Pesses, M. E., B. T. Tsurutani, J. A. Van Allen, and E. J. Smith, Acceleration of energetic protons by interplanetary shocks, J. Geophys. Res. **84**, 7297-7301, 1979.

Pesses, M. E., J. A. Van Allen, and C. K. Goertz, Energetic protons associated with interplanetary active regions 1-5 AU from the sun, J. Geophys. Res. **83**, 553-562, 1978.

Pesses, M. E., J. A. Van Allen, B. T. Tsurutani, and E. J. Smith, High time resolution observations of corotating interaction region proton events by Pioneer 11, J. Geophys. Res. **89**, 37-46, 1984.

Van Allen, J. A., B. A. Randall, and M. F. Thomsen, Sources and sinks of energetic electrons and protons in Saturn's magnetosphere, J. Geophys. Res. **85**, 5679-5694, 1980

Table I

Interplanetary Proton ($0.61 < E_p < 3.41$ MeV) Events

Pioneer 11/Detector G/University of Iowa

Year	Active Days	Day of Max. Intensity	j_{max} $(cm^2\ s\ sr)^{-1}$	r A.U.	λ	β
1973	101-111	103	356.3	1.01	204°.6	-0°.5
	120-123	120	53.8	1.06	225.3	-1.5
	127-130	128	1.3			
	134-141	135	15.8	1.15	241.2	-2.2
	155-161	156	14.6			
	161-169	163	113.8	1.37	264.3	-2.8
	177-190	177	1.8			
		183	1.5			
		188	1.2			
	193-198	196	11.0			
	209-219	214	19.6			
		216	19.4			
	238-242	238	110.5	2.06	298.6	-3.0
	247-249	249	1.3			
	252-262	254	133.1	2.21	303.2	-2.9
	270-274	271	2.7			
		274	8.4			
	295-312	298	5.7			
		302	7.3			
		304	2.7			
		307	1.4			
		310	1.7			
		312	1.2			
	326-330	327	23.7	2.82	318.2	-2.6
		329	16.1			
	337-338	338	6.8			
	350-356	351	7.2			
		354	47.2	3.03	322.3	-2.5
1974	2-5	4	2.6			
	12-27	15	34.9	3.21	325.6	-2.3
		23	23.9			
	30-33	30	1.3			
	39-72	40	43.3	3.39	328.7	-2.2
		44	12.4			
		47	13.0			
		49	27.5			
		64	47.2	3.55	331.3	-2.1
		72	1.3			

Year	Active Days	Day of Max. Intensity	j_{max} $(cm^2\ s\ sr)^{-1}$	r A.U.	λ	β
1974 (cont.)	73-94	76	38.1			
		83	2.0			
		86	1.9			
		91	6.9			
		94	3.2			
	102-113	103	27.1	3.79	335.0	-2.0
		106	5.3			
	116-139	120	21.3			
		131	5.5			
		135	3.5			
	141-148	142	1.8			
		144	3.8			
	157-169	159	17.5			
		162	4.7			
		166	13.0			
		168	88.3	4.16	340.3	-1.8
	180-198	181	2.5			
		184	2.7			
		192	20.5			
		195	180.9	4.30	342.3	-1.7
	216-224	220	76.0	4.43	343.9	-1.6
	232-252	233	3.2			
		238	3.8			
		244	42.3			
		246	93.2	4.55	345.6	-1.5
	255-278	256	25.7			
		262	13.2			
		267	15.8			
		270	32.4			
		273	71.1	4.68	347.2	-1.5
	281-289	282	7.1			
	297-305	299	8.5			
		301	24.7			
		303	18.0			
	307-319	307	25.1			
		315	2.1			
	321-329	323	27.2	4.90	350.0	-1.3
		326	7.2			
		329	3.7			
	330-348	Jupiter Encounter				
	352-361	354	2.5			
		359	8.0			

Year	Active Days	Day of Max. Intensity	j_{max} $(cm^2\ s\ sr)^{-1}$	r A.U.	λ	β
1975	7-16	8	19.8			
		11	17.0			
	35-42	36	33.6	4.66	357.4	0.8
		39	12.6			
	57-64	59	28.0			
	83-86	86	2.2			
	103-110	Data Gap				
	~ 111-114	111	23.5			
	130-136	132	4.4			
		134	6.0			
		136	5.1			
	155-163	156	1.8			
		159	25.3	4.17	13.0	5.0
	179-186	181	6.7			
		184	24.6			
	208-213	209	1.5			
		212	1.3			
	- -	245	1.0			
	289-296	293	7.0			
	- -	312	1.7			
	315-317	317	20.4	3.79	38.4	10.8
	333-336	336	2.2			
	342-344	343	10.4			
	363-	364	2.3			
1976*	-11	3	88.2	3.74	47.6	12.4
	25-30	28	29.4			
	51-56	52	132.3	3.74	56.7	13.6
	64-69	65	12.0			
	72-82	75	14.6			
		78	77.2			
	86-97	90	140.2	3.76	63.7	14.4
	102-104	102	2.3			
	116-119	117	1.6			
	127-132	128	19.8			
		132	5.2			
	145-147	146	1.5			
	151-156	152	43.7	3.85	75.0	15.1
	177-180	179	21.0			
	- -	205	2.6			
	- -	231	5.7			
	- -	254	1.2			

Year	Active Days	Day of Max. Intensity	j_{max} $(cm^2\ s\ sr)^{-1}$	r A.U.	λ	β
1976* (cont.)	- -	266	1.5			
	- -	283	4.0			
	332-333	332	0.9			
	- -	347	2.1			
	357-363	358	5.2			
1977	16-23	18	18.4	4.60	110.2	13.8
	- -	28	0.9			
	- -	44	0.9			
	204-205	204	1.8			
	215-223	219	4.4			
		222	1.4			
	- -	231	1.0			
	- -	248	1.1			
	- -	253	0.9			
	259-286	263	27.4	5.81	134.8	9.8
		271	3.8			
		280	105.5	5.85	135.3	9.7
	320-329	320	1.7			
		323	1.6			
		325	2.5			
		327	3.3			
	341-356	343	12.6			
		349	4.4			
		355	5.0			
1978	- -	12	1.1			
	20-27	24	122.8	6.41	142.6	8.1
	51-52	52	1.0			
	56-67	61	33.3			
	78-88	83	5.5			
	99-143	102	3.6			
		110	5.5			
		115	15.2			
		117	17.8			
		119	15.4			
		125	19.4			
		132	510.2	6.97	148.6	6.7
	165-171	168	3.5			
	190-201	193	10.5			
	207-218	210	59.4	7.37	152.4	5.8
	259-260	259	1.3			

Year	Active Days	Day of Max. Intensity	j_{max} $(cm^2\ s\ sr)^{-1}$	r A.U.	λ	β
1978 (cont.)	274-304	280	2.5			
		283	3.4			
		294	2.4			
		302	4.4			
	308-311	308	2.4			
		311	1.2			
	349-358	356	3.7			
1979	- -	16	2.0			
	- -	20	1.0			
	24-27	27	1.1			
	59-64	61	1.2			
	74-81	75	8.0	8.53	161.4	3.4
		78	4.8			
	109-123	112	3.0			
		114	2.6			
		119	1.3			
		123	1.0			
	- -	137	0.9			
	155-189	158	1.3			
		162	1.9			
		165	1.7			
		174	11.1	9.02	164.5	2.6
		180	2.7			
		185	2.8			
	205-219	207	2.9			
		209	2.7			
	226-230	229	1.6			
	236-242	239	27.7	9.34	166.4	2.0
	243-251	Saturn Encounter				
	252-288	270	299.1	9.35	168.1	2.4
	330-335	332	1.2			
1980*	68-70	70	1.5			
	108-118	112	1.3			
	125-128	126	2.7			
	157-159	158	1.9			
	181-189	181	6.2			
		184	2.7			
		187	1.3			
	234-246	237	1.3			
	251-265	253	3.0			
		259	4.6			
		263	7.9	9.66	189.0	8.3

Year	Active Days	Day of Max. Intensity	j_{max} $(cm^2\ s\ sr)^{-1}$	r A.U.	λ	β
1980 (cont.)	312-359	316	1.7			
		330	2.3			
		339	2.1			
		344	18.0	9.85	193.5	9.4
1981	71-73	72	1.8			
	88-93	90	4.4			
	111-113	111	1.1			
	117-168	118	2.5			
		130	9.0			
		134	10.9			
		139	38.2			
		155	68.8	10.40	202.8	11.5
	231-233	232	8.4			
	271-280	272	1.3			
	283-318	284	1.4			
		286	18.4	10.90	208.9	12.8
		300	7.1			
		305	10.4			
	328-338	333	1.4			
1982	63-72	67	4.0			
		69	4.0			
	125-129	126	2.3			
	148-150	149	1.2			
	175-231	181	26.4	12.11	219.6	14.5
		189	13.1			
		191	14.9			
		200	4.0			
		206	7.9			
		214	54.0	12.28	220.8	14.7
	261-264	262	0.9			
	271-274	272	1.3			
	286-291	287	5.9			
	296-318	296	2.2			
		300	3.7			
		314	3.1			
	325-329	328	1.5			
	343-	344	3.1			
		354	3.9			
		361	105.7	13.07	225.9	15.3

Year	Active Days	Day of Max. Intensity	j_{max} $(cm^2\ s\ sr)^{-1}$	r A.U.	λ	β
1983	-20	7	7.0			
	24-32	27	12.0			
	64-65	64	1.7			
	85-88	86	4.1			
	117-120	120	2.2			
	134-148	135	2.2			
		142	1.3			
		145	1.6			
	193-197	196	1.9			
1984*	71-83	80	4.3			
	87-92	87	1.7			
	105-109	107	15.9	15.90	238.6	16.3
	111-120	112	2.2			
		115	2.2			
	132-154	133	2.1			
		150	1.5			
	176-179	176	1.0			
	246-256	248	2.1			
	277-285	278	1.7			
		282	1.7			
	344-352	349	1.9			
1985	6-8	8	1.0			
	28-30	28	3.0	17.73	244.3	16.6
	- -	40	1.5			
1986	- -	14	1.8			
	89-92	91	2.1			
1987	- -	1	-	22.40	254.2	16.6

Notes:

(1) * indicates leap year.

(2) Day numbers begin with 1 January = Day 1 of each year.

(3) j_{max} is the daily mean absolute unidirectional intensity for the day of an intensity peak.

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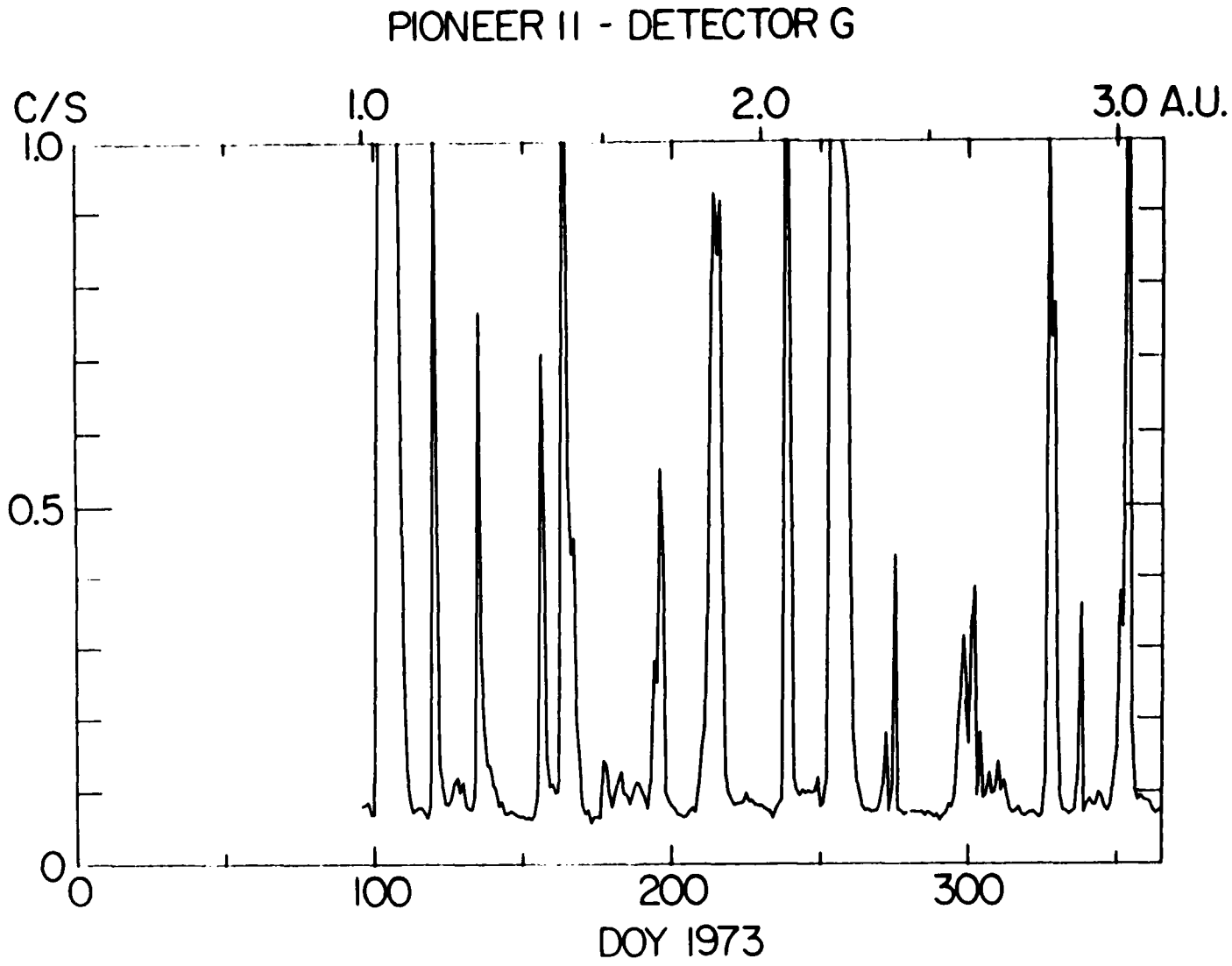

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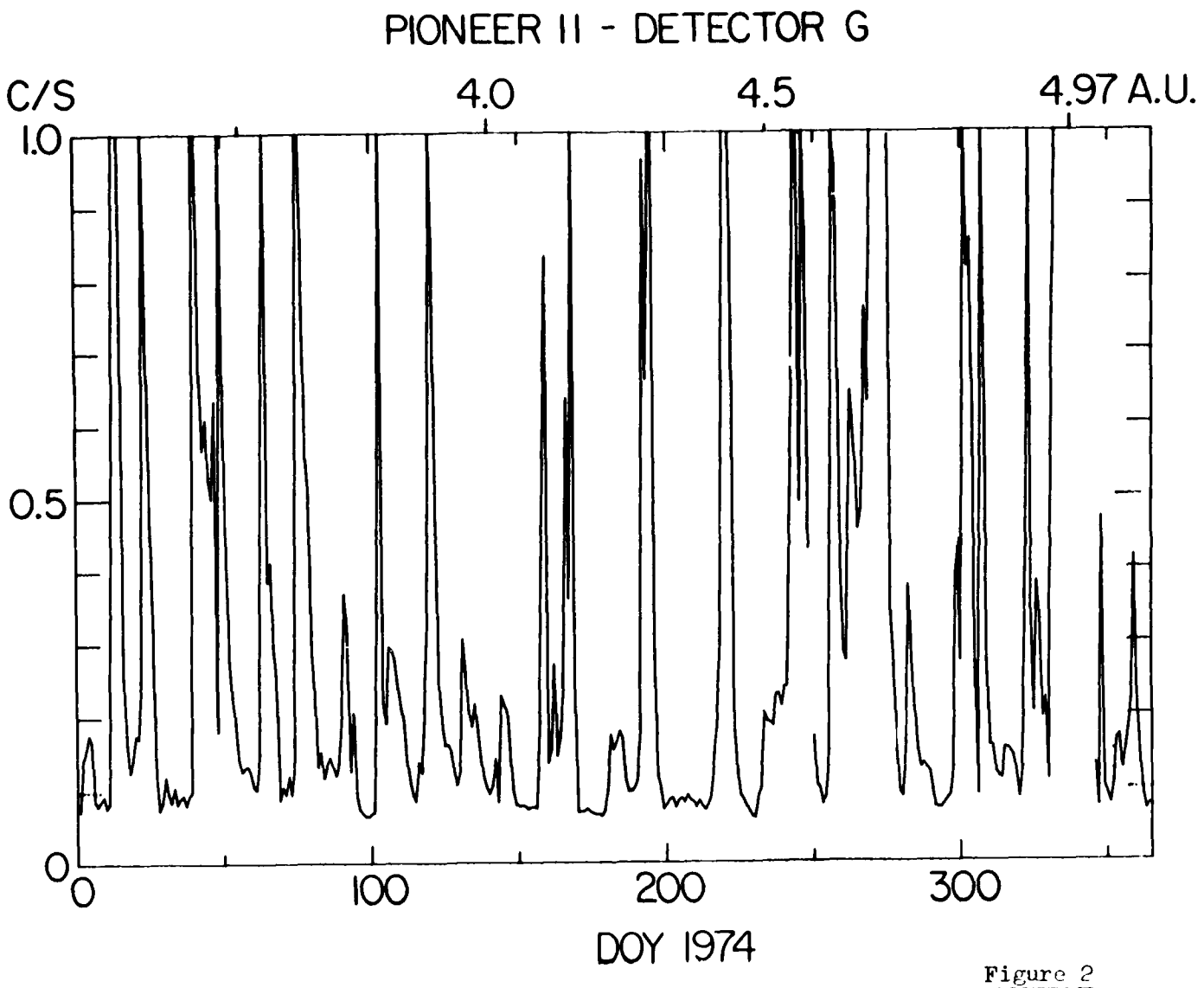

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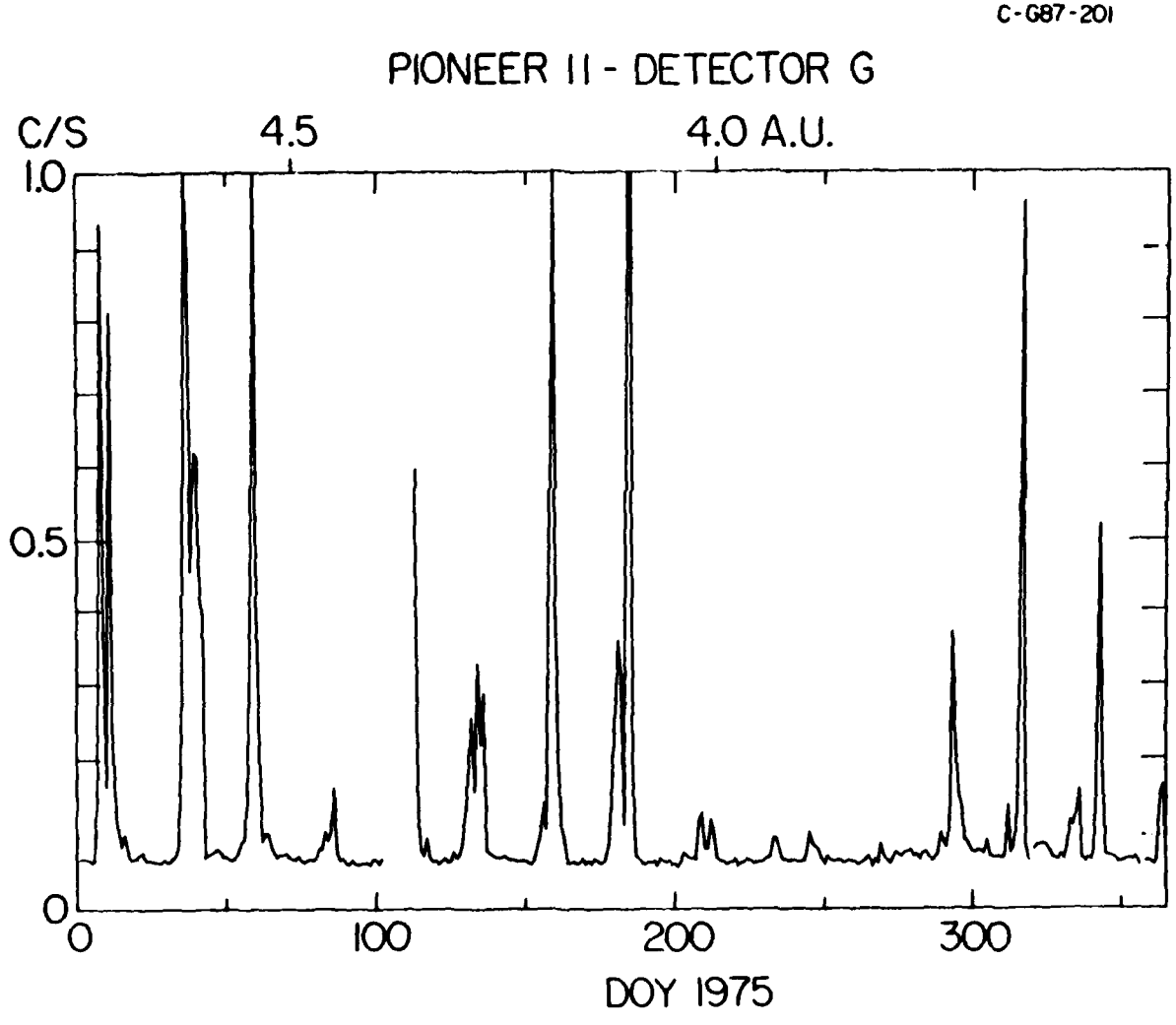
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Figure 3

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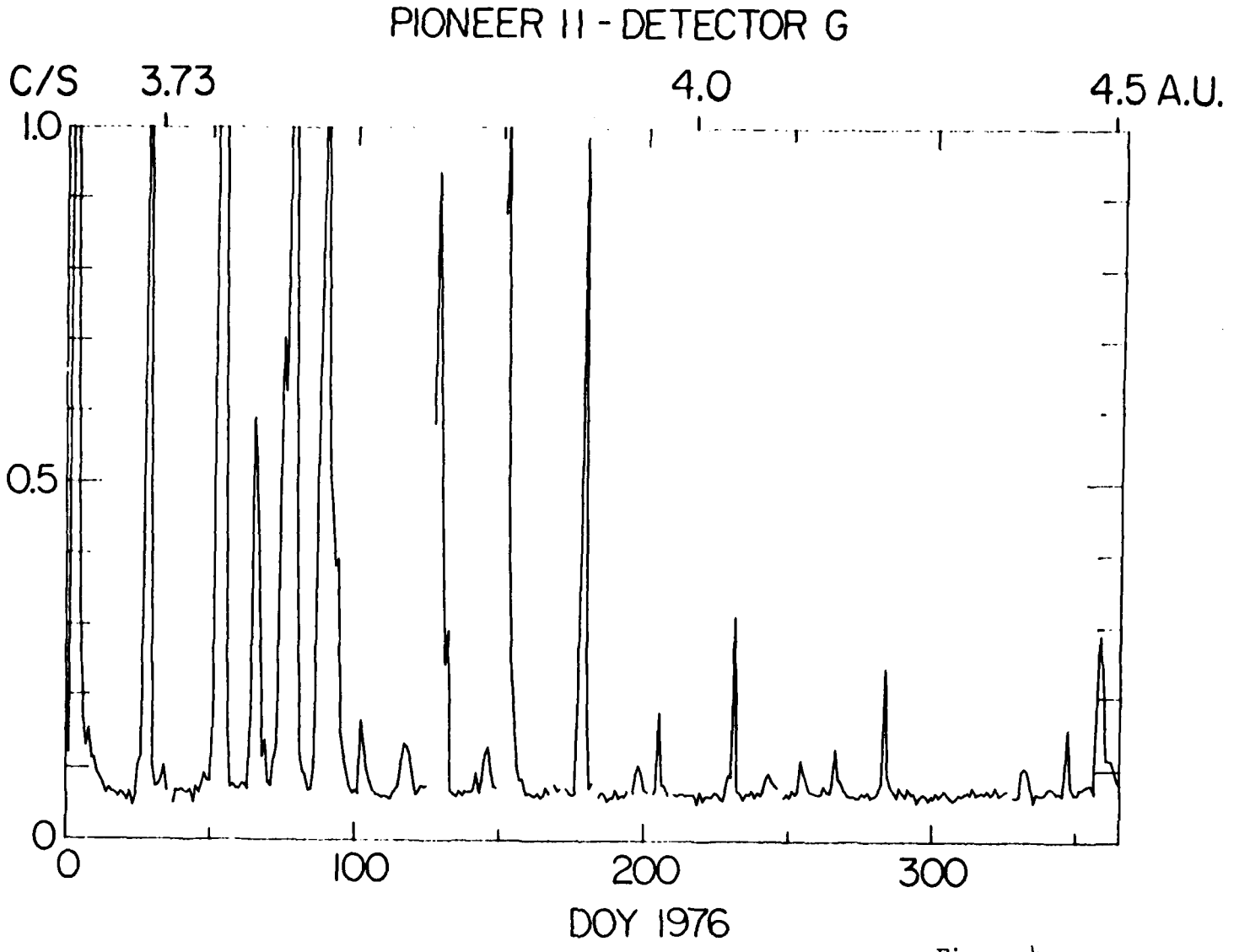

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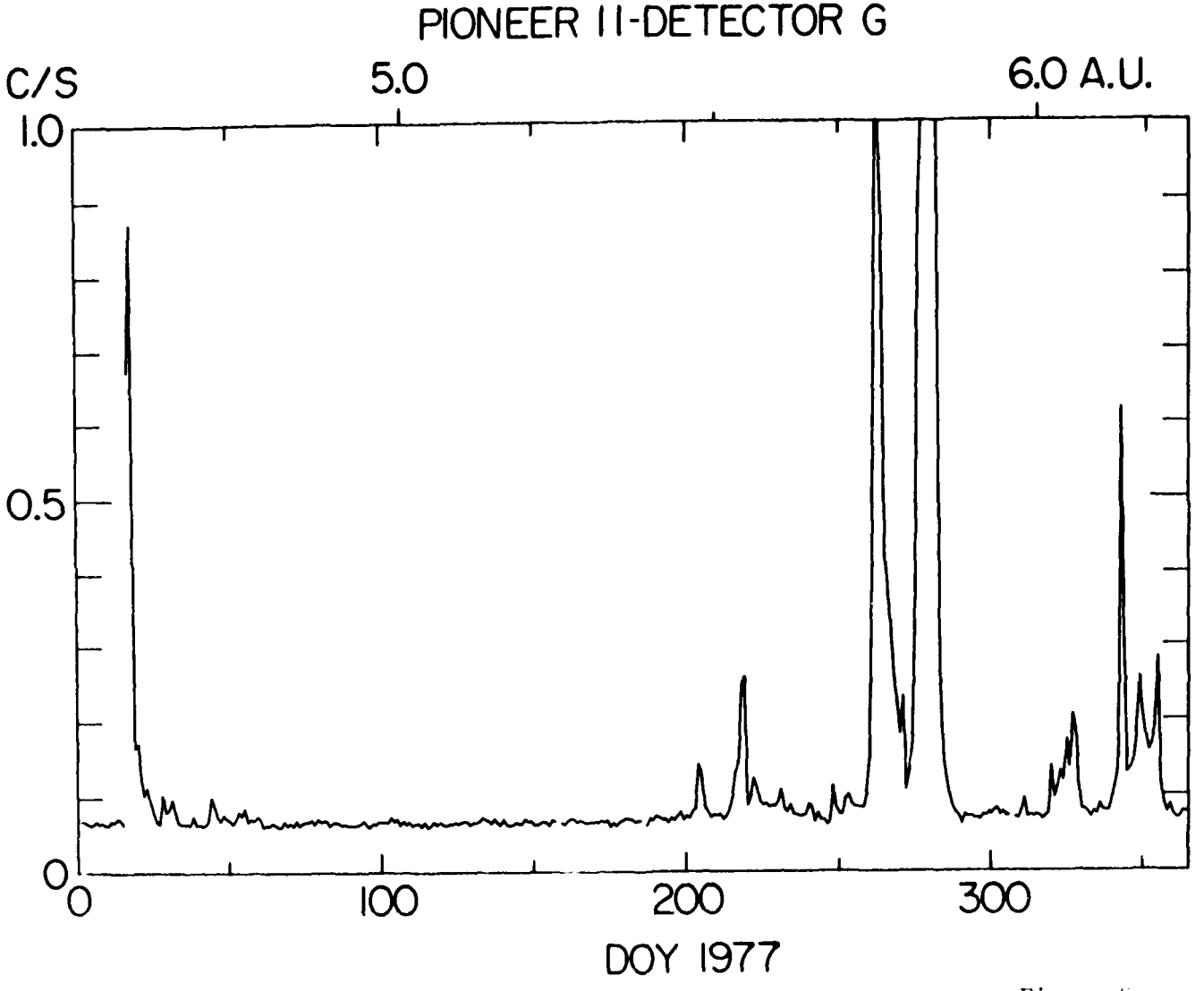

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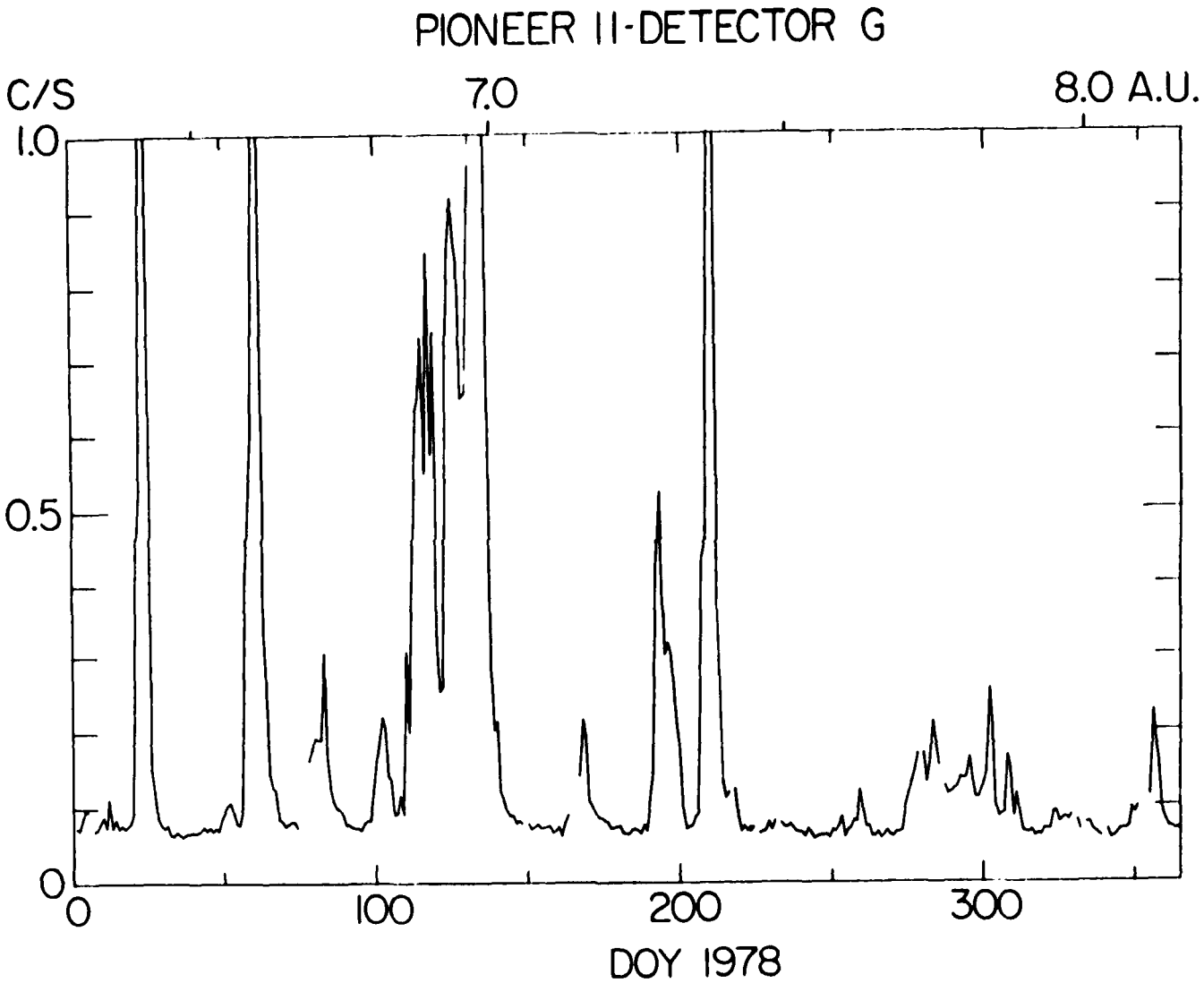

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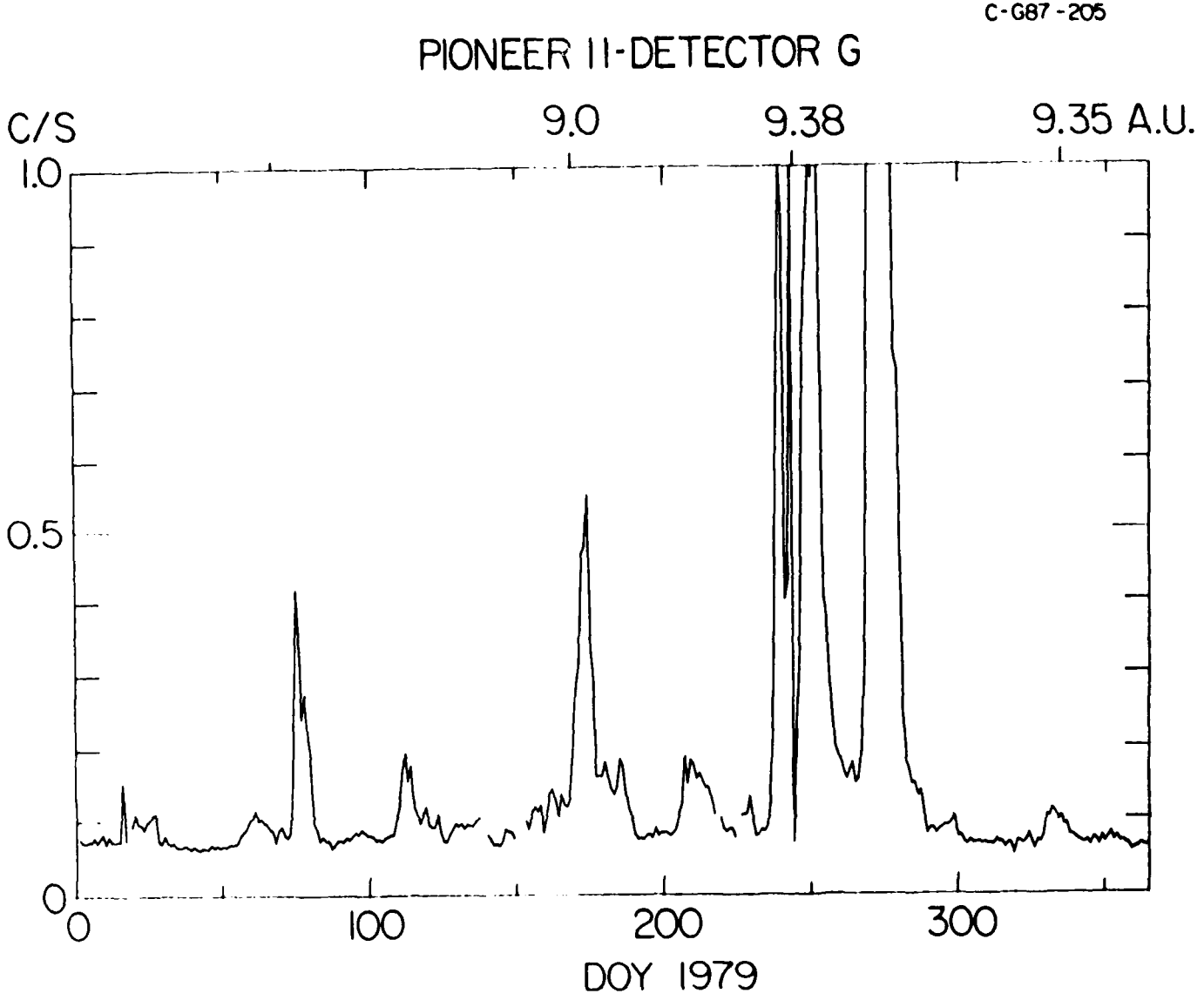
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DOY 1979

Figure 1

C-G87-206

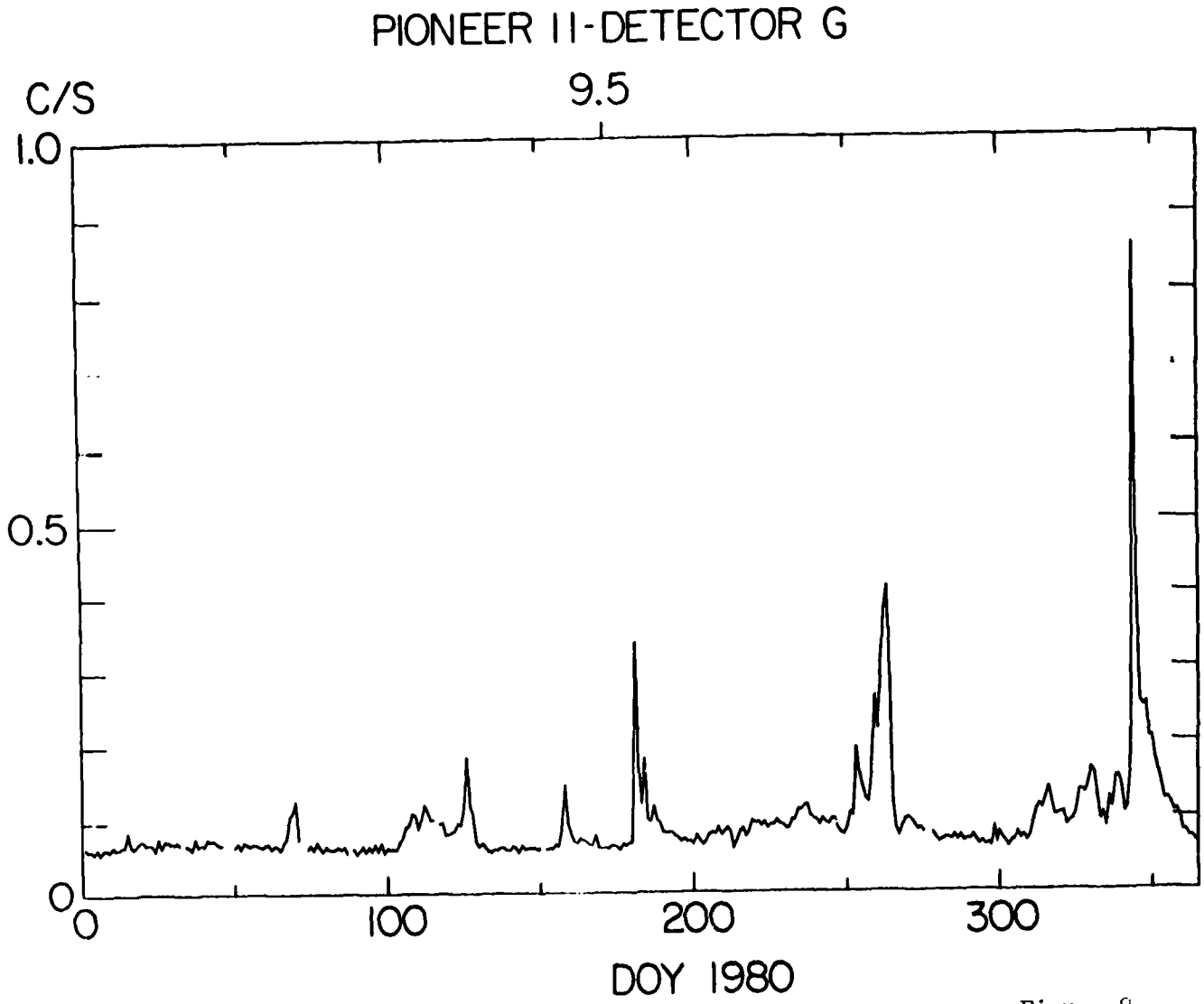

Figure 8

C-G87-207

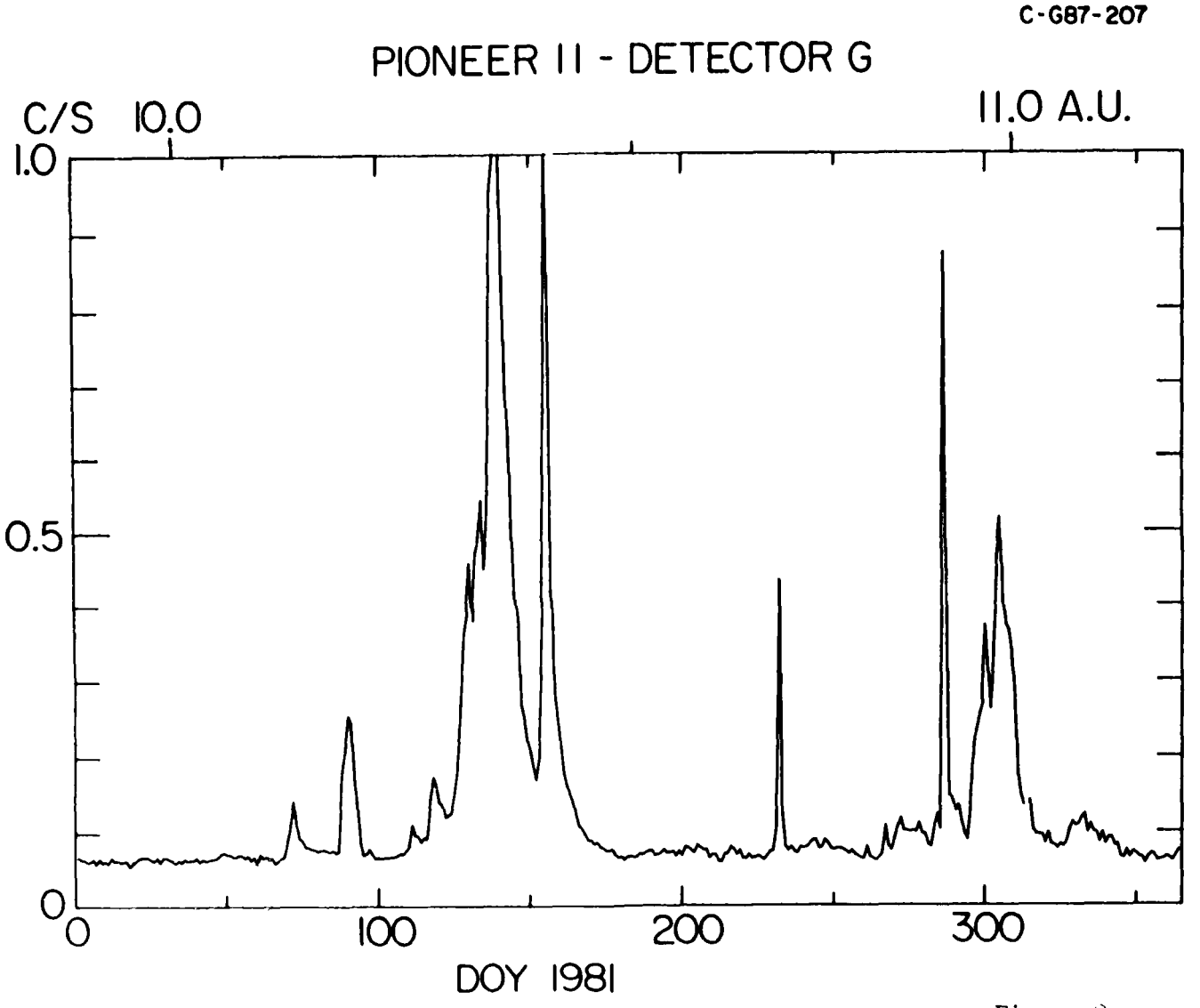

Figure 9

C-G87-208

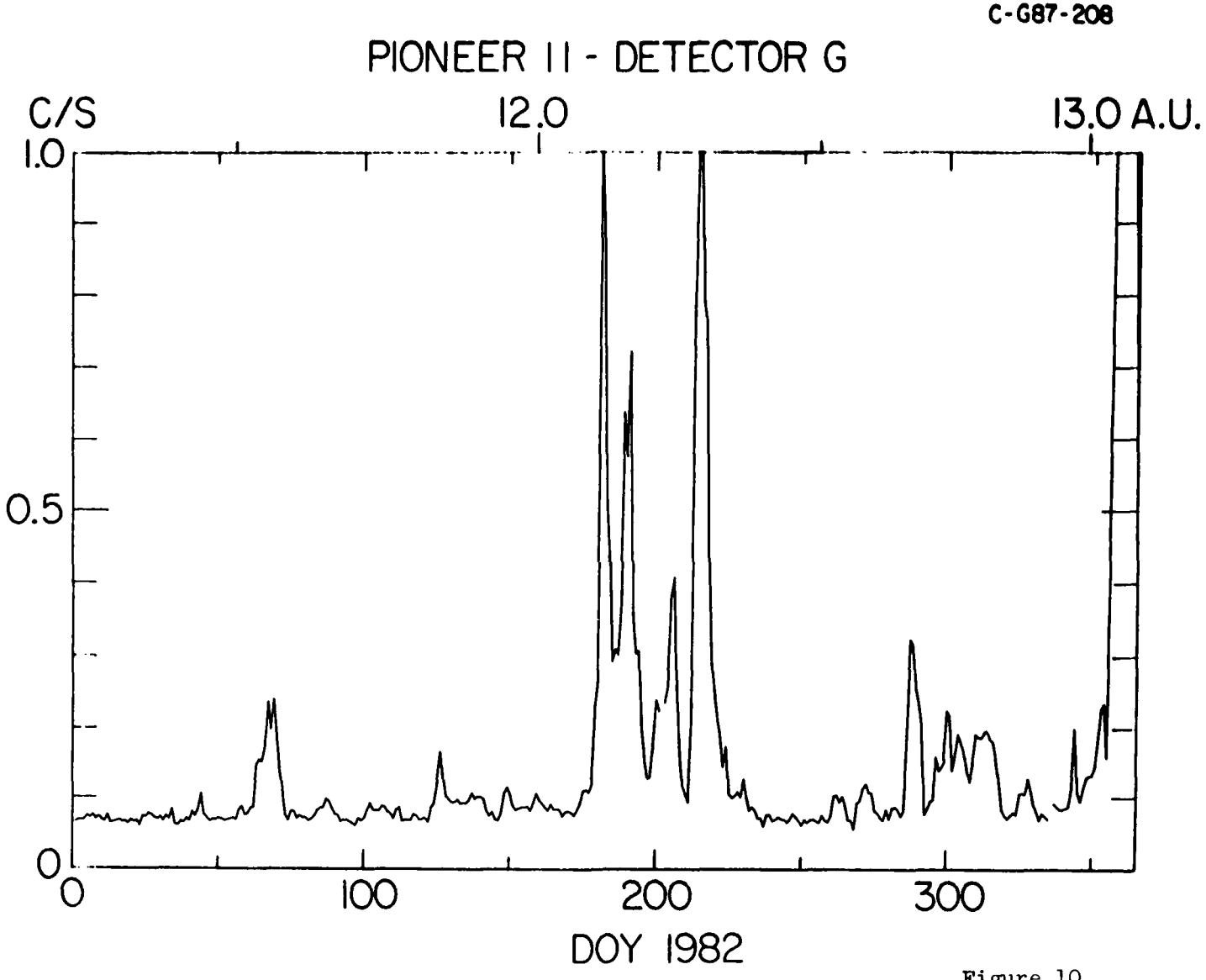

Figure 10

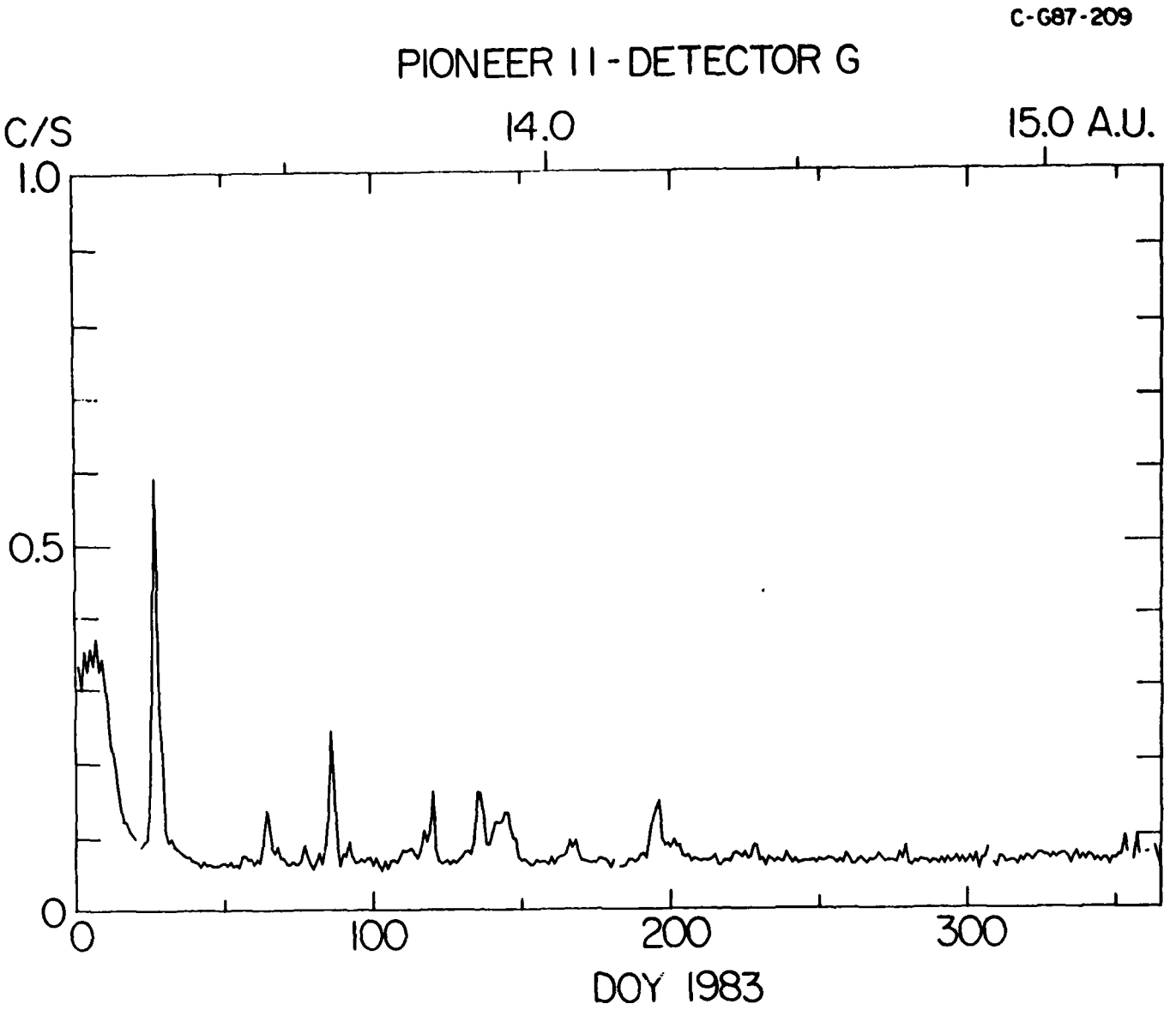
C-G87-209
PIONEER 11 - DETECTOR G
C/S
14.0
15.0 A.U.
1.0
0.5
0
0
100
200
300
DOY 1983

Figure 11

C-G87-210

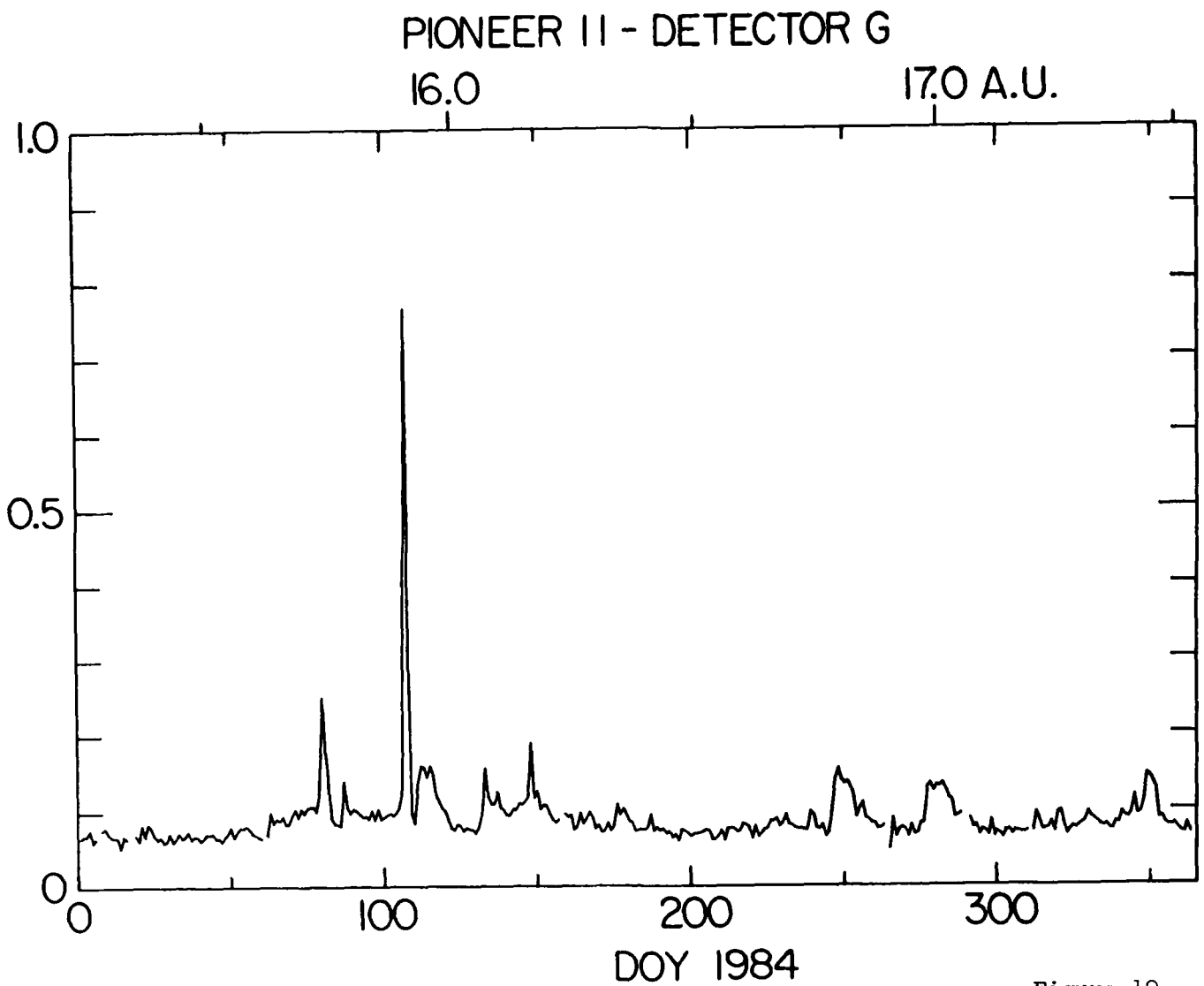

Figure 12

C-G87-211

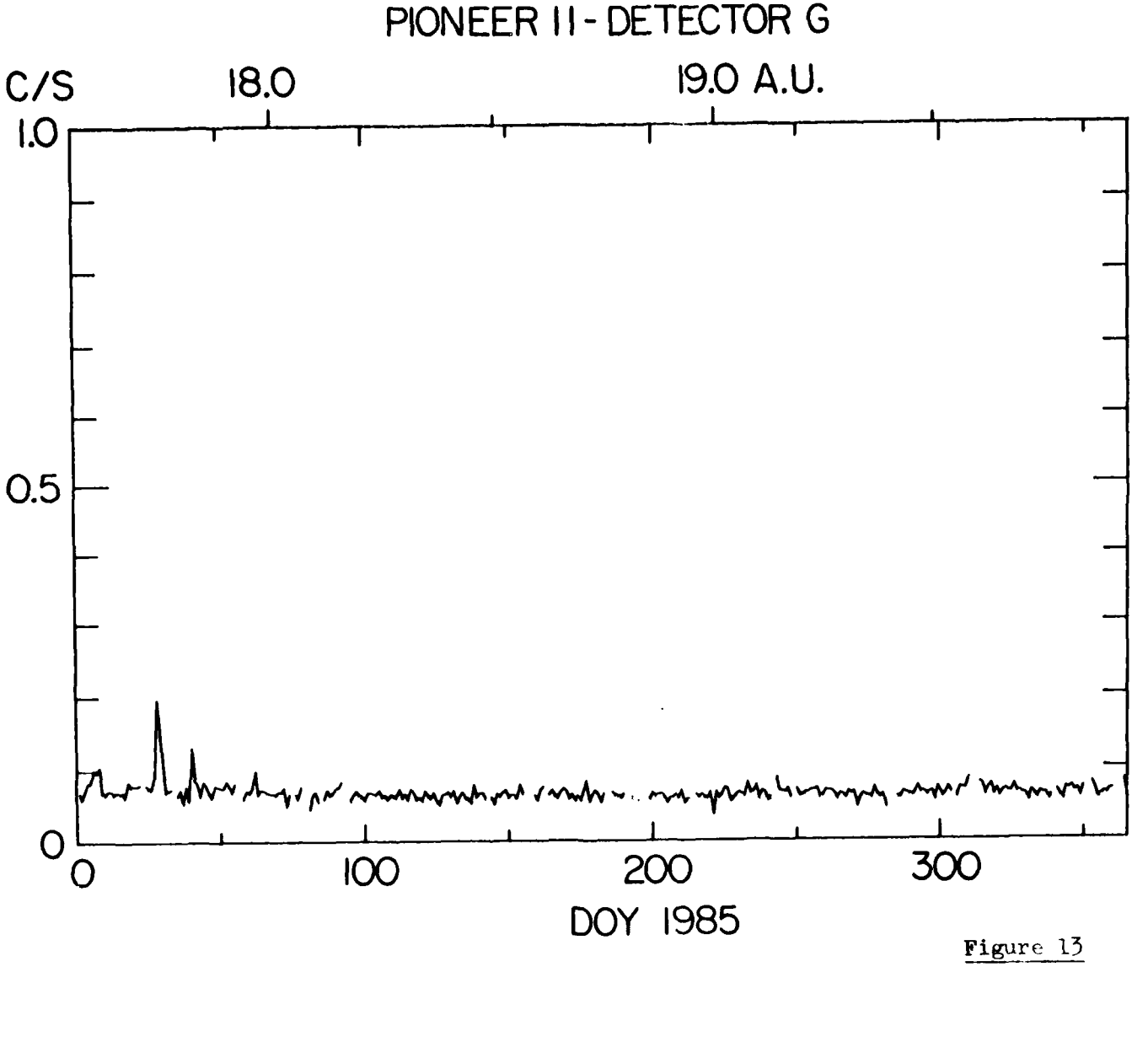

Figure 13

C-G87-212

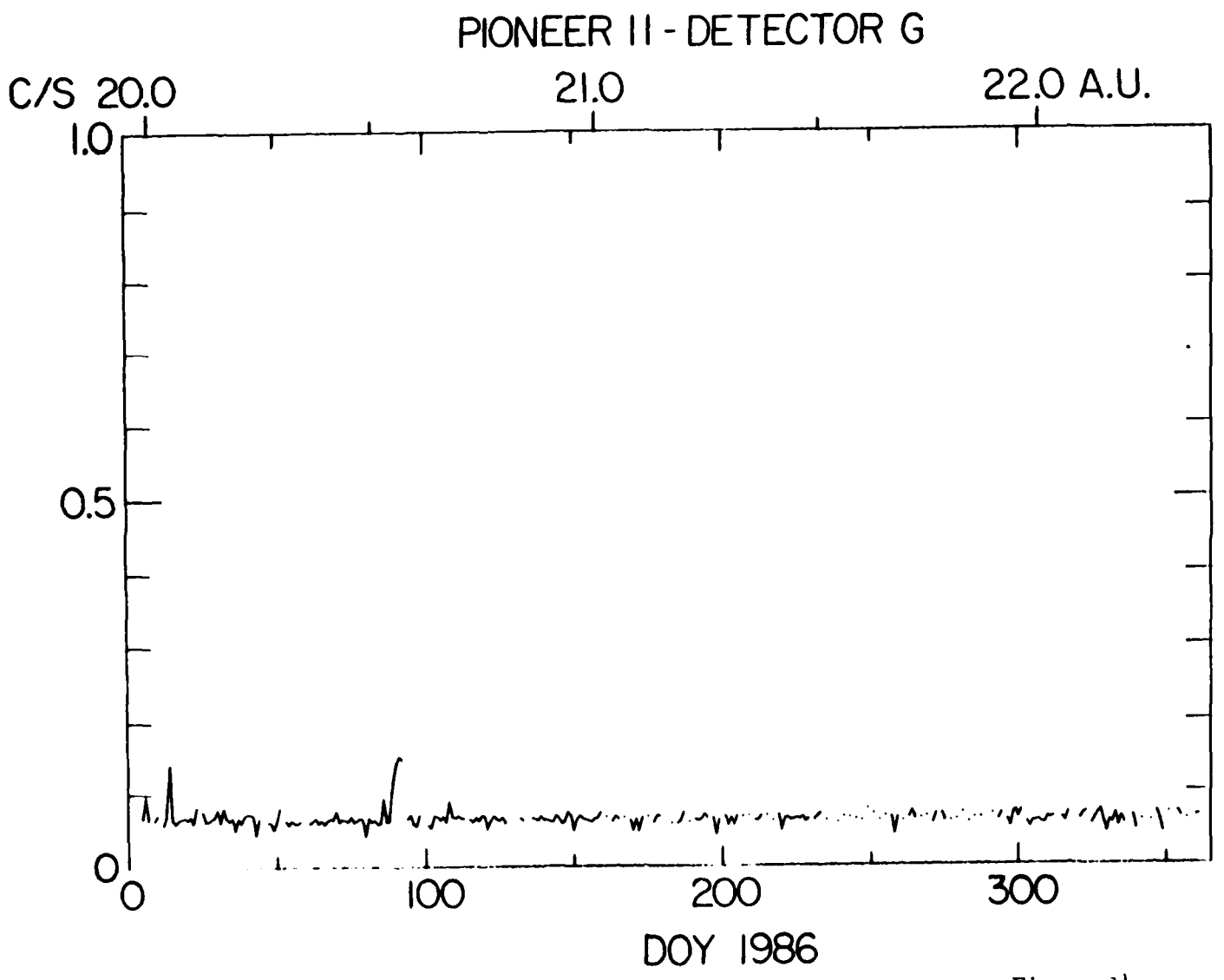

Figure 14

EMD

9-87

DTIC