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THE ANALYSIS OF THE X-RAY EVENT ANALYZER PROPORTIONAL COUNTER DATA: A COMMENT

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February 1977

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George C. Marshall Space Flight Center
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16. ABSTRACT

During the Skylab mission (May 1973 through February 1974), the X-ray event analyzer (X-REA), a part of the ATM/S-056 X-ray telescope experiment, monitored the 2.5 to 7.25 Å and 6.1 to 20 Å solar X-ray fluxes. As the mission progressed, it became apparent that the proportional counters of the X-REA were decreasing in sensitivity. This report presents findings, based on a comparison of simultaneous observations of a number of flares obtained with the X-REA and SOLRAD 9 instruments, which reveal the degree of deterioration of the counters with time. These corrections can then be applied to observed data, thus allowing a more accurate determination of the flux levels during the late mission phases and, thereby, extending the usefulness of the X-REA as a plasma diagnostic tool.

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THE ANALYSIS OF THE X-RAY EVENT ANALYZER PROPORTIONAL COUNTER DATA: A COMMENT

I. INTRODUCTION

During the Skylab mission (May 1973 through February 1974), in particular the Apollo Telescope Mount (ATM) operational periods, proportional counters were used to monitor the Sun's 2.5 to 7.25 Å and 6.1 to 20 Å X-ray fluxes. These proportional counters and their electronics formed the X-ray event analyzer (X-REA), a part of the Skylab ATM/S-056 X-ray telescope experiment. The X-REA not only provided monitor information regarding flares and other transient events and their relative intensities, but also obtained data that could be used to determine temperature and density distributions for these events.

In a preceding report,[1] Wilson [1] described the X-PEA and the techniques employed in the analysis of its data to determine plasma parameters and alluded to the deterioration of the counters with time. The purpose of this report, then, is to address the question of X-REA deterioration more fully.

II. PROPORTIONAL COUNTER DETERIORATION

The X-REA consisted of two conventional, coaxial proportional counters, designated the beryllium counter (2.5 to 7.25 Å) and aluminum counter (6.1 to 20 Å), respectively, because of their window material. The beryllium counter

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1. In the preceding paper (Wilson [1]), the data rate of the X-REA was erroneously given as 20 bits/2.5 s. Its rate was actually 20 bits/0.25 s or or 80 bits s^{-1} (10 channels read sequentially every 0.25 s, each channel representing a 20 bit word). Also, the length dimension was inaccurately given as 0.183 m. Its true value is 0.813 m. Figure 5 normalized X-REA beryllium total should be 3.57×10^5 (for peak), not 3.75×10^5, and Figure 6 normalized X-REA aluminum total should be 2.18×10^6 (for peak), not 2.18.

had a gas mix of 90:10 xenon to methane, and the aluminum counter had a gas mix of 90:10 argon to methane. Both counters separated their pulses into a number of energy channels, using pulse-height analysis techniques, so that a degree of spectral resolution could be attained.

During the course of the Skylab mission, both X-REA counters showed a decrease in sensitivity with time; i.e., peak counts were significantly lower for an M1 X-ray event[2] observed late in the mission as compared to one observed early in the mission. Furthermore, individual channel ratios, which gave reasonable results early in the mission, gave unacceptable values later in the mission. Previous attempts to understand these problems were hampered by invalid aperture-position indications contained in the telemetered data and by the use of data which included high background counts. Thus, the initial curves showed a gradual fall-off in sensitivity of the X-REA counters with time with occasional erroneous recoveries.

Proportional counters degrade with time because of either electronics problems or tube problems or a combination of the two. Electronics problems are understood to be changes in the way the pulses are sorted and prepared prior to telemetry. One example of this is multiple-photon counting. Tube problems are understood to be either high-voltage changes on the tube or the build-up of "crud" or deposits on the central wire anode which causes local electric-field anomalies. Tube problems, thus, cause gain changes which affect the interpretation of the data.

An examination of the X-REA data suggests that the tubes were the apparent source for the observed X-REA deterioration. A review of the telemetry record indicated no change in the calibration count signals as a function of time. The calibration signals were included in the instrument to provide an inflight functional check of the electronics. They were terminated when the high-voltage power supplies for the counters were turned on. No onboard calibration source was provided.

Apparently, the methane gas polymerized as a function of time and the impurities in the gas mix reacted with the tungsten wire central anode, leaving a deposit. (Such deposits are known to affect the local electric-field geometry in proportional counters.) Another contributing factor may have been variation in the high-voltage power supplies. Unfortunately, no monitor was provided to

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2. An M1 X-ray event is one whose peak 1 to 8 Å X-ray emission is at least 1×10^{-2} erg cm^{-2} s^{-1} but less than 2×10^{-2} erg cm^{-2} s^{-1}, as measured by the ionization chamber onboard SOLRAD 9.

check the stability of the high voltage on the tubes as a function of time. Therefore, this too may have added to the X-REA deterioration. (Underwood [2] has briefly commented on the gain change problem, especially as related to the aluminum counter.)

III. APPROACH

To illustrate the decrease in sensitivity of the X-REA counters with time, X-REA data for a number of flares have been compared with simultaneously observed SOLRAD 9 data. The events used in this study were extracted from a larger listing of observed X-REA events [3]. The approach used in this study was the following: Assume that the SOLRAD 9 data accurately describe all the events included in the comparison; i.e., the peak values measured by the 1 to 8 Å and 8 to 20 Å ionization chambers are correct. Next, assume that the physical parameters of the 15 June 1973 event (see Reference 1), especially peak temperature and peak 2.5 to 7.25 Å flux, were accurately determined from the X-REA. Then, by comparing similar ratios for a certain event (i.e., SOLRAD 9 data for that event with SOLRAD 9 data for the 15 June event which should be approximately equal to the X-REA data for the same event as compared to the X-REA data for the 15 June event), one should be able to obtain an X-REA calculated value for the event under investigation. Finally, by dividing the calculated value into the observed value, one determines the degradation of the counter. One should remember to only compare the similar wavelength bands with each other, i.e., the X-REA 2.5 to 7.25 Å data with the SOLRAD 9 1 to 8 Å data and the X-REA 6.1 to 20 Å data with the SOLRAD 9 8 to 20 Å data. Differences in the wavelength bands have been neglected for this study. The SOLRAD 9 values have been visually read from Solar-Geophysical Data. Also, since SOLRAD 9 memory data represent 1 min averages, the X-REA data have been averaged accordingly.

IV. DISCUSSION

The 15 June 1973 1B/M3 event is used as a calibration point, since it is a major flare that occurred early in the first Skylab mission when the X-REA should be free of the deterioration which became apparent in the later phases of the mission. (Wilson [4] has overviewed the analysis results to date of the 15 June event.)

Temperature determinations for this event have been performed by a number of investigators (see Widing and Cheng [5], Palavicini et al. [6], Widing and Dere [7], Henze et al. [8], and Wilson [1,4]). An average peak temperature value of approximately 14×10^6 K is suggested from these studies. All investigators find the temperature peaking at approximately 1412 UT. Further, Wilson [1] has shown a highly accurate correspondence between X-REA 2.5 to 7.25 Å flux and SOLRAD 9 1 to 8 Å flux. Therefore, using this information, one can calculate the X-REA 6.1 to 20 Å flux and compare it to the observed value to ascertain the degree of "noise" known to be present in the 6.1 to 20 Å flux in the early mission.[3] Calculated values can also be obtained for the peak flux time which occurred at approximately 1415 UT.

Table 1 summarizes the SOLRAD 9 and X-REA observed values for 1412 UT and 1415 UT. Assuming that the beryllium counter (2.5 to 7.25 Å) did accurately monitor the flux and that the temperature of the event was 14×10^6 K, one finds that the ratio of beryllium total counts (Be T, i.e., the counts in all energy channels over the 2.5 to 7.25 Å band) to aluminum total counts (Al T, i.e., the counts in all energy channels over the 6.1 to 20 Å band) for the 14×10^6 K plasma is equal to 3.94×10^{-1} [1]. This implies that the Al T value for 1412 UT should be equal to 7.4×10^5 counts cm^{-2} s^{-1}, or that the observed value of Al T at 1412 UT is 2.2 times too high. A comparison of the Be T value at 1412 UT to the Be T value at 1415 UT shows that the observed Be T value at 1415 UT is in perfect agreement with the calculated value. A similar calculation to determine the calculated Al T value at 1415 UT based on the calculated Al T value at 1412 UT shows that its value is 1.3×10^6 counts cm^{-2} s^{-1}, or that the observed Al T value at 1415 UT is 1.7 times too high. Table 2 summarizes these calculated X-REA values for the peak flux period of the 15 June 1973 event, which then serves as the calibration check for all the other events included in this study (i.e., all events are compared with the calculated Be T and Al T 1415 UT values).

Table 3 is a compilation of the flares used in this study, giving the date of the flare occurrence, its X-ray class, the region where it occurred, the time of maximum Hα emission, the SOLRAD 9 observed peak values, the X-REA calculated peak values, and the degradation factor for each tube. Only those events which were simultaneously observed by the X-REA and SOLRAD 9 and which appeared to be free of high background counts are included. Thus, 37 events, occurring on 28 different days, comprise the listing.

3. The word "noise" does not refer to the statistical spread of the data, as is more commonly used, but refers to the discrepancy between observed count rates and predicted count rates. During the first mission, the aluminum counter displayed too many counts. This discrepancy was not apparent at the start of the second mission.

Figure 1 illustrates the sensitivity decrease as a function of time as observed for the beryllium counter, and Figure 2 shows the degradation as observed for the aluminum counter. In both figures, the rate of sensitivity decrease is greatest for the second manned Skylab mission (denoted SL3) which covers the period 7 August through 22 September 1973 (Day of Years 219 through 265). During this period, the beryllium counter appeared to decrease from 1.0 to approximately 0.06, remaining approximately 0.06 between DOY's 256 and 265. In contrast, the aluminum counter degraded from 1.0 to approximately 0.1 between DOY's 219 and 253 and appeared to flatten after DOY 253 at a value of approximately 0.09. During SL4, both counters continued to degrade, but at a much slower rate. For example the beryllium counter sensitivity decreased from 0.06 to approximately 0.05 and the aluminum counter sensitivity decreased from 0.07 to approximately 0.06.

The decrease in sensitivity in the counters indicates that while the normal ratio methods work adequately in the first mission (i.e., ratios of Be channels 6 to 5 and/or Be channels 5 and 6 to aluminum channels 3 and 4 [1]), they would yield spurious results for part of the second and all of the last manned missions without compensating for the sensitivity fall-off. Thus, one can use these curves to correct the Be T and Al T observed counts and then use the Be T/Al T ratio for determining temperatures and emission measures of events occurring through the last manned mission. In this way, one can extend the usefulness of the X-REA as a plasma diagnostic tool into even the last mission.

In Figure 3, the SOLRAD 9 1 to 8 Å data are compared with the calculated X-REA 2.5 to 7.25 Å data for the events listed in Table 3. Thus, one can use Figure 3 to determine X-REA 2.5 to 7.25 Å corrected count rates based on the SOLRAD 9 1 to 8 Å data or, vice versa, knowing the X-REA 2.5 to 7.25 Å corrected count rates, one can determine the equivalent SOLRAD 9 1 to 8 Å data. Furthermore, one can use the X-REA 2.5 to 7.25 Å corrected data to determine the X-ray class of those flares which were not observed by SOLRAD 9. Figure 4 shows a similar comparison, based on the SOLRAD 9 8 to 20 Å data and the X-REA 6.1 to 20 Å corrected data.

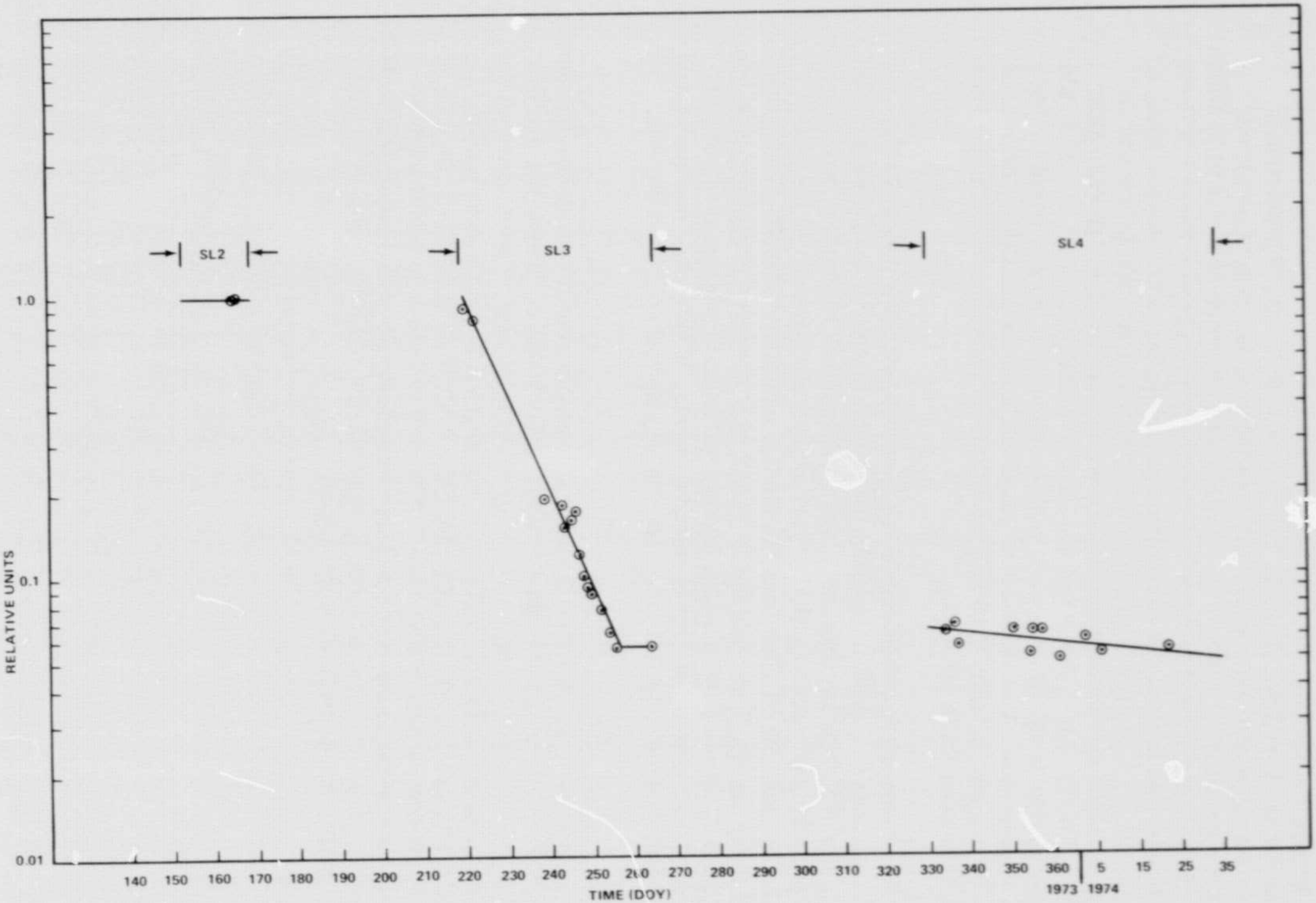

Figure 1. Degradation of the X-REA beryllium counter (2.5 to 7.25 Å) during Skylab, based on comparison with SOLRAD 9 1 to 8 Å data.

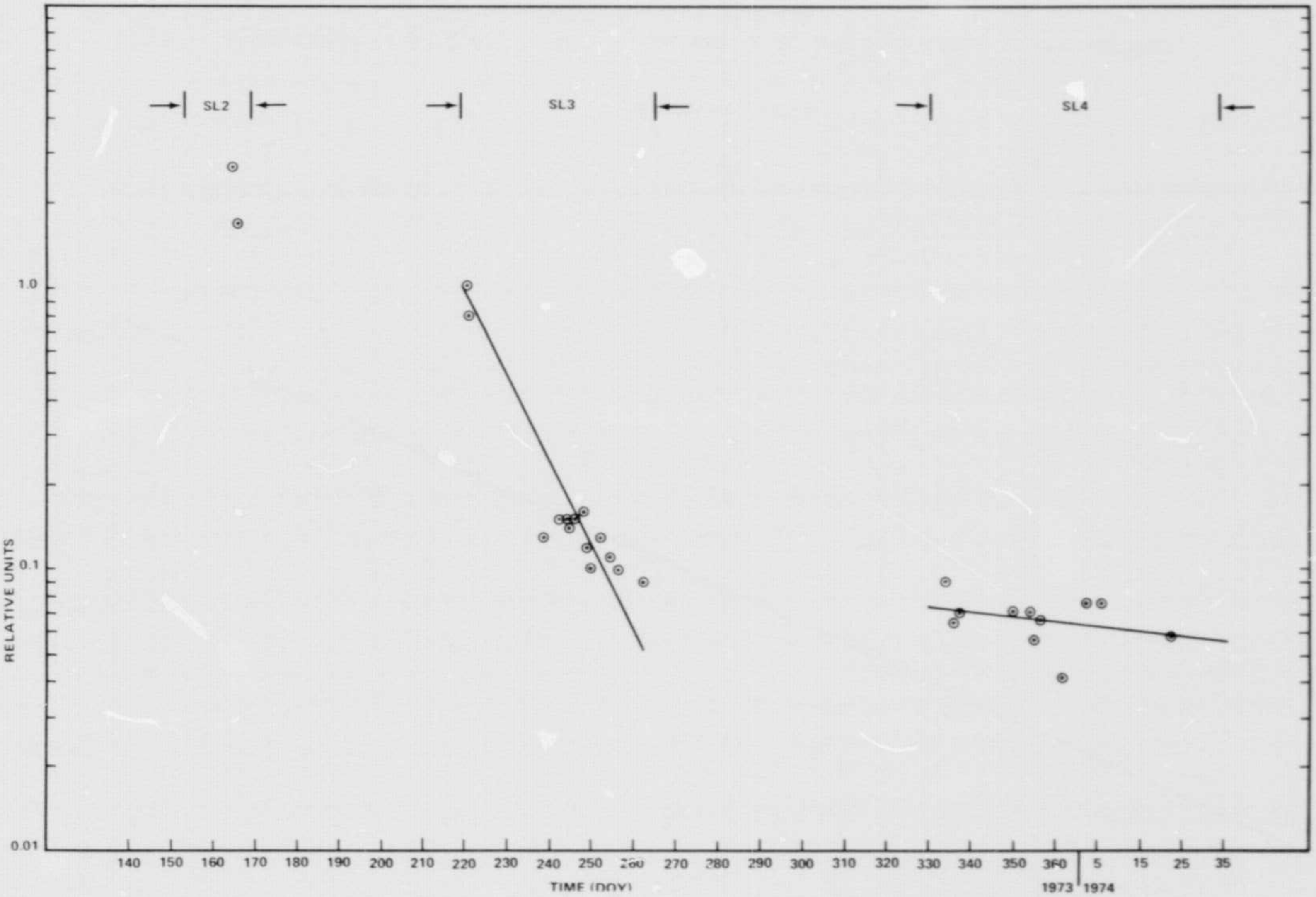

Figure 2. Degradation of the X-REA aluminum counter (6.1 to 20 Å) during Skylab, based on comparison with SOLRAD 9 8 to 20 Å data.

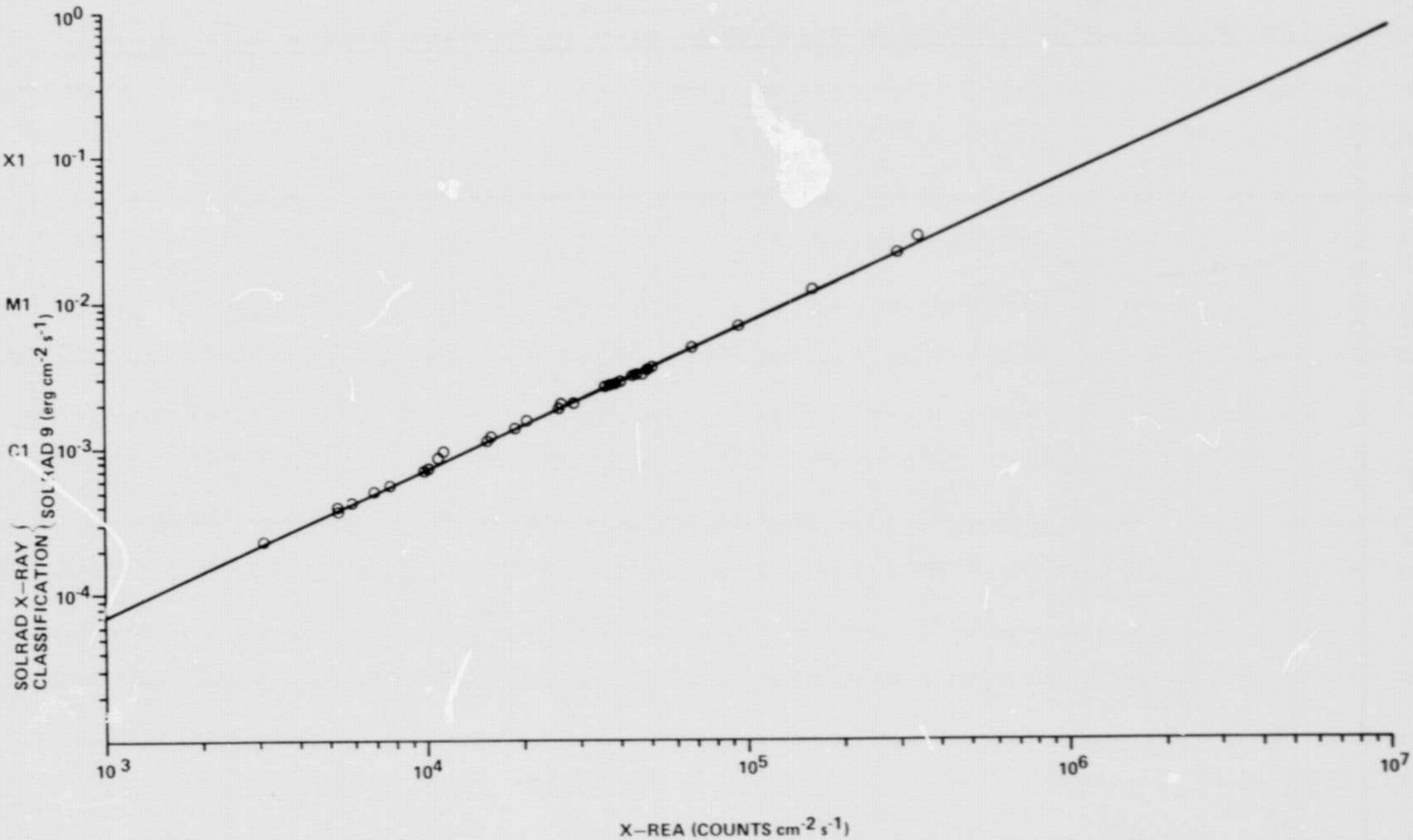

Figure 3. Comparison of SOLRAD 9 1 to 8 Å flux with X-REA 2.5 to 7.25 Å corrected flux for selected flares during Skylab.

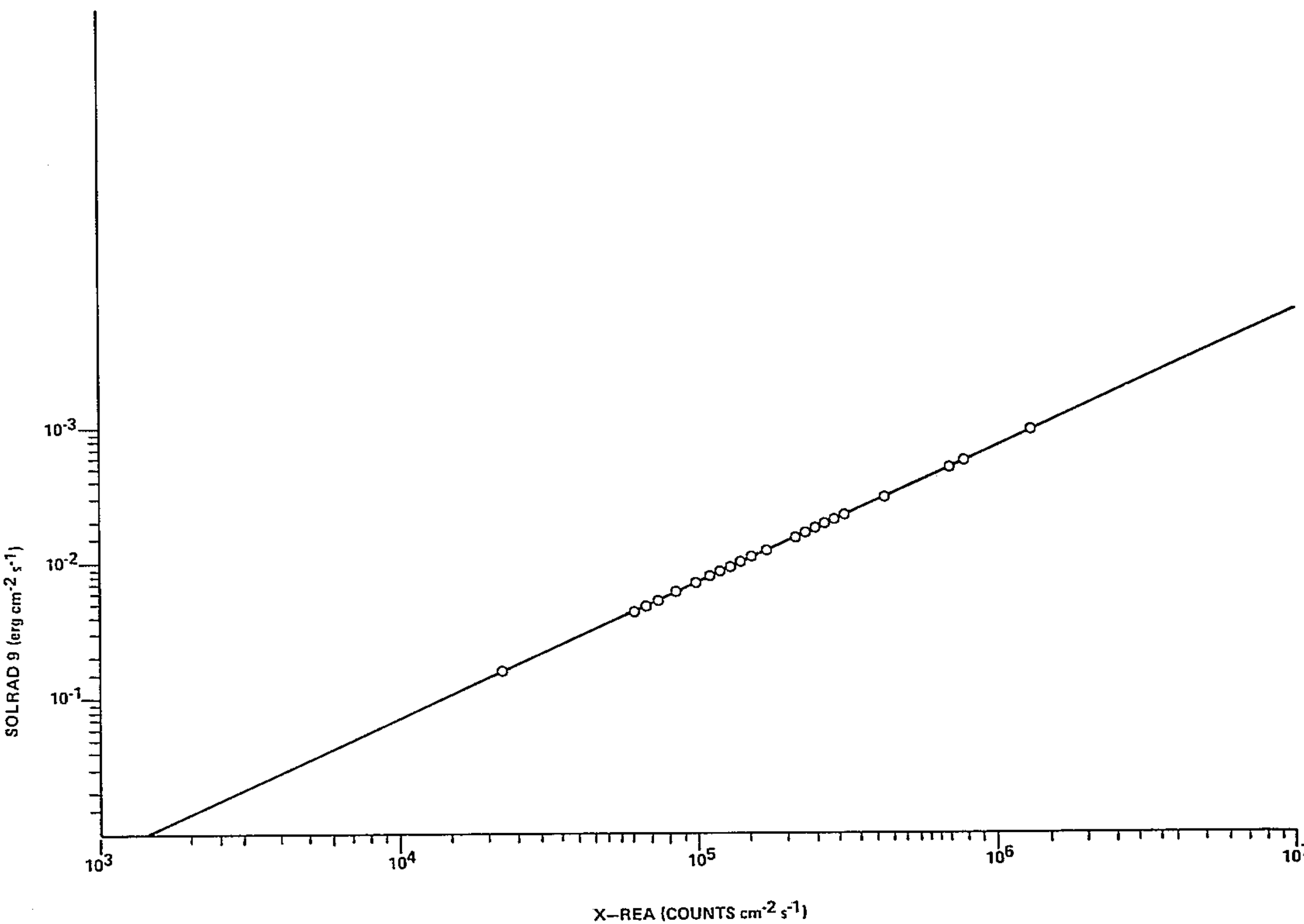

Figure 4. Comparison of SOLRAD 9 8 to 20 Å flux with X-REA 6.1 to 20 Å corrected flux for selected flares during Skylab.

TABLE 1. SOLRAD 9 AND X-REA OBSERVED VALUES OF FLUX FOR SELECTED TIMES DURING THE 15 JUNE 1973 FLARE

Time (UT)	SOLRAD ($erg\ cm^{-2}\ s^{-1}$)		X-REA ($counts\ cm^{-2}\ s^{-1}$)	
	1-8 Å	8-20 Å	Be T	Al T
1412	2.2×10^{-2}	5.3×10^{-2}	2.9×10^{5}	1.6×10^{6}
1415	2.7×10^{-2}	9.3×10^{-2}	3.6×10^{5}	2.2×10^{6}

TABLE 2. X-REA CALCULATED VALUES OF FLUX FOR THE 15 JUNE 1973 FLARE AT 1415 UT

X-REA (1415 UT) ($counts\ cm^{-2}\ s^{-1}$)	
Be T	Al T
3.6×10^{5}	1.3×10^{6}

TABLE 3. OBSERVED AND CALCULATED VALUES OF PEAK FLUX FOR SELECTED FLARES DURING SKYLAB

Date	Class	Maximum	NOAA Region No.	SOLRAD 9		X-REA Observed		X-REA Calculated		Degradation Factor	
				1-8 Å	8-20 Å	Be T	Al T	Be T	Al T	Be T	Al T
14 June (165)	C0	0047-0058	127	9 (-4)	8 (-3)	1.2 (4)	3 (5)	1.2 (4)	1.1 (5)	1.0	2.7
15 June (166)	M3	1413	131	2.7 (-2)	9.3 (-2)	3.6 (5)	2.2 (6)	3.6 (5)	1.3 (6)	1.0	1.7
8 August (220)	C3	2340	185	3.5 (-3)	1.5 (-2)	4.1 (4)	2.1 (5)	4.7 (4)	2.1 (5)	8.7 (-1)	1.0
9 August (221)	M1	1553	185	2.2 (-2)	5.5 (-2)	2.5 (5)	6.4 (5)	2.9 (5)	7.7 (5)	8.6 (-1)	8.3 (-1)
9 August (221)	C2	2148	185	2.1 (-3)	8 (-3)	2.3 (4)	8.8 (4)	2.8 (4)	1.1 (5)	8.2 (-1)	8.0 (-1)
27 August (239)	C0	0928	208	4.4 (-4)	5.3 (-3)	1.1 (3)	9.4 (3)	5.9 (3)	7.4 (4)	1.9 (-1)	1.3 (-1)
31 August (243)	C1	1419	209	1.6 (-3)	1.1 (-2)	3.8 (3)	2.4 (4)	2.1 (4)	1.5 (5)	1.8 (-1)	1.6 (-1)
31 August (243)	C3	1931	212	3 (-3)	1.6 (-2)	7.1 (3)	3.1 (4)	4 (4)	2.2 (5)	1.8 (-1)	1.4 (-1)
1 September (244)	C2	1829	209	1.6 (-3)	1.2 (-2)	4.1 (3)	2.7 (4)	2.1 (4)	1.7 (5)	2.0 (-1)	1.6 (-1)
1 September (244)	C4	2126	215	3.7 (-3)	1.9 (-2)	6.3 (3)	4.4 (4)	4.9 (4)	2.7 (5)	1.3 (-1)	1.6 (-1)
1 September (244)	C1	2311	215	1.2 (-3)	1.2 (-2)	2.2 (3)	2.4 (4)	1.6 (4)	1.7 (5)	1.4 (-1)	1.4 (-1)
2 September (245)	C4	0045	215	3.5 (-3)	1.9 (-2)	6.9 (3)	3.7 (4)	4.7 (4)	2.7 (5)	1.5 (-1)	1.4 (-1)
2 September (245)	C2	0831	218	2 (-3)	1.7 (-2)	4.1 (3)	3.5 (4)	2.7 (4)	2.4 (5)	1.5 (-1)	1.5 (-1)
2 September (245)	C4	1629	215	3.1 (-3)	2.2 (-2)	8.3 (3)	4.2 (4)	4.1 (4)	3.1 (5)	2.0 (-1)	1.4 (-1)
3 September (246)	C1	0302	211	1.3 (-3)	1.1 (-2)	2.9 (3)	2.3 (4)	1.7 (4)	1.5 (5)	1.7 (-1)	1.5 (-1)
4 September (247)	C7	1635	212	7 (-3)	3 (-2)	1.1 (4)	6.2 (4)	9.3 (4)	4.2 (5)	1.2 (-1)	1.5 (-1)
5 September (248)	C4	0924	209	4 (-3)	2 (-2)	5.2 (3)	4.4 (4)	5.3 (4)	2.8 (5)	9.8 (-2)	1.6 (-1)
6 September (249)	C3	1624	209	2.8 (-3)	1.8 (-2)	3.3 (3)	2.9 (4)	3.7 (4)	2.5 (5)	8.9 (-2)	1.2 (-1)
7 September (250)	C2	0213	209	2 (-3)	1.7 (-2)	2.7 (3)	2.5 (4)	2.7 (4)	2.4 (5)	1.0 (-1)	1.0 (-1)
7 September (250)	C2	1925	210	2.1 (-3)	1.8 (-2)	2.1 (3)	2.6 (4)	2.8 (4)	2.5 (5)	7.5 (-2)	1.0 (-1)
9 September (252)	C1	0820	219	1 (-3)	9 (-3)	[illegible] (3)	1.7 (4)	1.5 (4)	1.3 (5)	7.7 (-2)	1.3 (-1)
11 September (254)	C1	1555	219	1.6 (-3)	1 (-2)	1.3 (3)	1.6 (4)	2.7 (4)	1.4 (5)	6.2 (-2)	1.1 (-1)
13 September (256)	C0	0647	219	5.8 (-4)	6 (-3)	4.3 (2)	8.7 (3)	7.7 (3)	8.4 (4)	5.6 (-2)	1.0 (-1)
21 September (264)	C0	2017	236	4 (-4)	4.8 (-3)	3 (2)	5.9 (3)	5.3 (3)	6.7 (4)	5.7 (-2)	8.8 (-2)
30 November (331)	C1	0227	287	1.4 (-3)	7.5 (-3)	1.2 (3)	9.3 (3)	1.9 (4)	1 (5)	6.3 (-2)	9.3 (-2)
2 December (336)	M1	1518	292	1.3 (-2)	5 (-2)	1.1 (4)	3.9 (4)	1.7 (5)	7 (5)	6.5 (-2)	5.2 (-2)
2 December (336)	C5	2010-2020	292	5 (-3)	1.9 (-2)	4.6 (3)	2.1 (4)	6.7 (4)	2.7 (5)	6.9 (-2)	7.8 (-2)
3 December (337)	C2	0207	292	2(-3)	1 (-2)	1.5 (3)	1 (4)	2.7 (4)	1.4 (5)	5.6 (-2)	7.1 (-2)
16 December (350)	C0	1317	300	7.5 (-4)	8 (-3)	6.4 (2)	8 (3)	1 (4)	1.1 (5)	6.4 (-2)	7.3 (-2)
20 December (354)	C2	1326	300	1 (-3)	8 (-3)	6.9 (2)	7.8 (3)	1.3 (4)	1.1 (5)	5.3 (-2)	7.1 (-2)
21 December (355)	C0	1939	300	4.2 (-4)	7 (-3)	3.5 (2)	5.3 (3)	5.6 (3)	9.8 (4)	6.3 (-2)	5.4 (-2)
22 December (356)	C0	0023	300	5.2 (-4)	6.1 (-3)	4.2 (2)	5.7 (3)	6.9 (3)	8.5 (4)	6.1 (-2)	6.7 (-2)
27 December (361)	C1	2017	300	1.3 (-3)	8.5 (-3)	8.7 (2)	7.2 (3)	1.7 (4)	1.2 (5)	5.1 (-2)	6.0 (-2)
2 January (002)	C0	1614	312	2.3 (-4)	1.6 (-3)	1.8 (2)	1.7 (3)	3.1 (3)	2.2 (4)	5.8 (-2)	7.7 (-2)
6 January (006)	C0	2231	312	7.4 (-4)	4.4 (-3)	5.2 (2)	4.7 (3)	9.9 (3)	6.2 (4)	5.3 (-2)	7.6 (-2)
22 January (022)	C3	1746	331	3.3 (-3)	1.5 (-2)	2.5 (3)	1.2 (4)	4.4 (4)	2.1 (5)	5.7 (-2)	5.7 (-2)
22 January (022)	C2	2118	331	2.9 (-3)	1.1 (-2)	2.1 (3)	9.5 (3)	3.9 (4)	1.5 (5)	5.4 (-2)	6.3 (-2)

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APPROVAL

THE ANALYSIS OF THE X-RAY EVENT ANALYZER PROPORTIONAL COUNTER DATA: A COMMENT

By Robert M. Wilson

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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