SD76-MSFC-2040

SD76-M...

Final Report

RESEARCH IN SOLAR PHYSICS

(NASA-CR-150157) RESEARCH IN SOLAR PHYSICS Final Report (Teledyne Brown Engineering) 42 p HC A03/MF A01 CSCL 03B
N77-15971
Unclas
G3/92 12639

September 30, 1976

TELEDYNE
BROWN ENGINEERING

Cummings Research Park • Huntsville, Alabama 35807

FINAL REPORT
SD76-MSFC-2040

RESEARCH IN SOLAR PHYSICS

September 30, 1976

Prepared For

GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA

Contract No. NAS 8-26442

Prepared By

SYSTEMS ANALYSIS DEPARTMENT
SYSTEMS DIVISION
TELEDYNE BROWN ENGINEERING
HUNTSVILLE, ALABAMA

ABSTRACT

Results from research in solar physics related to the Skylab/ATM S-056 X-Ray Experiment are presented. Included is a description of the data obtained by the X-Ray Telescope; it is intended for use by the National Space Science Data Center. Also presented are the S-056 filter bandpasses, the point-spread function, the meaning or interpretation of broadband filter observations, and reports on the analysis of some of the solar observations.

APPROVED:

William Henze

William Henze
Principal Investigator

N E Chatterton

N. E. Chatterton
Manager, Research

Frank R. Deis for

W. A. Grenard
Manager, Systems Analysis Department

TABLE OF CONTENTS

1. INTRODUCTION

Work under Contract NAS8-26442 encompassed a variety of different tasks. This final report contains results from some of these areas.

First, a preliminary description is given of the data from the Skylab/ATM Marshall Space Flight Center/Aerospace Corporation S-056 X-Ray Telescope. This is an extract from a larger document describing the data from the entire experiment including the X-Ray Event Analyzer. The larger report will be published as a NASA Technical Memorandum and submitted to the National Space Science Data Center.

Next, the S-056 filter bandpasses are given with slightly different definitions from those used earlier. The point-spread function is then presented with information on how it was obtained.

The interpretation of the broadband filter observations is discussed next. Finally, work on some solar observations is summarized.

2. PRELIMINARY DESCRIPTION OF THE DATA FROM THE SKYLAB/ATM S-056 X-RAY TELESCOPE

2.1 INSTRUMENT

This section contains a brief description of the S-056 X-ray telescope and provides information about instrumental properties needed to interpret the observations. These instrumental properties include the telescope collecting area, focal length, filter transmissions, and mirror reflectivities.

The glancing incidence X-ray telescope was of Wolter's Type 1 configuration and contained two mirrors, a paraboloid and a hyperboloid, made of fused silica. A shield and first stop prevented solar radiation from heating the front of the instrument and also shielded the film from direct X-rays. The entrance aperture was thus an annulus. A second stop within the telescope prevented rays that underwent only a single reflection from reaching the film.

The camera assembly consisted of a filter wheel to isolate different spectral bands, a shutter, a replaceable film magazine holding 304.8 m of film, an airlock door to maintain humidity inside the magazine, and an optical system to project the image of an array of data block lights onto the film. The data block lights, to be described later, provided auxiliary information about each exposure.

The whole instrument was mounted rigidly to the ATM spar by four thermal isolation mounts and thus shared the pointing of the entire spar. There were no provisions for internal motions of the S-056 telescope relative to the ATM spar.

A list of the important parameters of the telescope, including the focal length and the collecting area, is given in Table 1.

The S-056 X-ray telescope contained five thin filters of metallic foil to isolate broad wavelength bands in the soft X-ray spectrum. A sixth filter yielded an image in the visible portion of the spectrum but the resulting photographs were generally overexposed. The filters were mounted on a wheel whose position was normally changed after each exposure.

TABLE 1. S-056 X-RAY TELESCOPE PARAMETERS

Focal Length	190.3 cm
Collecting Area	14.66 cm^2
Usable Field of View	38 arc min
Plate Scale	9.23 μm/arc sec
Internal Diameter at Intersection of Two Mirrors	24.35 cm
Average Glancing Angle of Incidence on Each Mirror for Paraxial Rays	0.916 deg

The characteristics of the filters are summarized in Table 2. The product of the filter transmission and the reflectivities of the mirrors at the average angle of incidence is shown in Figures 1 through 3 as a function of wavelength for each of the X-ray filters.

2.2 OPERATING MODES

The S-056 instrument was capable of operating only during those portions of the three manned missions when the ATM console was attended by a Skylab astronaut.

Several operating modes were available in which filter changes and selection of exposure time and time between exposures were normally done in preset sequences chosen by the astronaut to optimize the observations of a particular solar phenomenon. Each sequence had to be initiated by the astronaut. Within each mode, three sets of exposure times were available. These were denoted as Short, Normal, and Long, with the Short exposures being a factor of 3.2 shorter than the Normal and the Long exposures a factor of 3.2 longer. The nominal exposure times for the Patrol and Active modes are given in Table 3.

TABLE 2. FILTER CHARACTERISTICS OF S-056 X-RAY TELESCOPE

The wavelength range is the region where the transmission exceeds 10^{-3}. The transmission used for both the peak and the range is the product of the filter transmission and the reflectivities of the mirrors.

FILTER	MATERIAL	THICKNESS (mg cm^{-2})	WAVELENGTH RANGE (Å)	WAVELENGTH AT PEAK TRANSMISSION (Å)	PEAK TRANSMISSION
1	0.50-mil Aluminum	3.42	8.0 to 14.6	8.0	0.17
2	0.25-mil Aluminum	1.71	6.2 to 7.6 8.0 to 19.5	8.0	0.33
3	0.086-mil Titanium	0.99	6.1 to 12.5 27.3 to 39.9	7.5	0.093
4	1-mil Beryllium	4.62	6.1 to 16.6	7.9	0.29
5	3-mil Beryllium	13.86	6.1 to 11.8	[illegible] 4	0.097
6	Multi-Layer Dielectric Interference Filter		80 (FWHM)	6328	

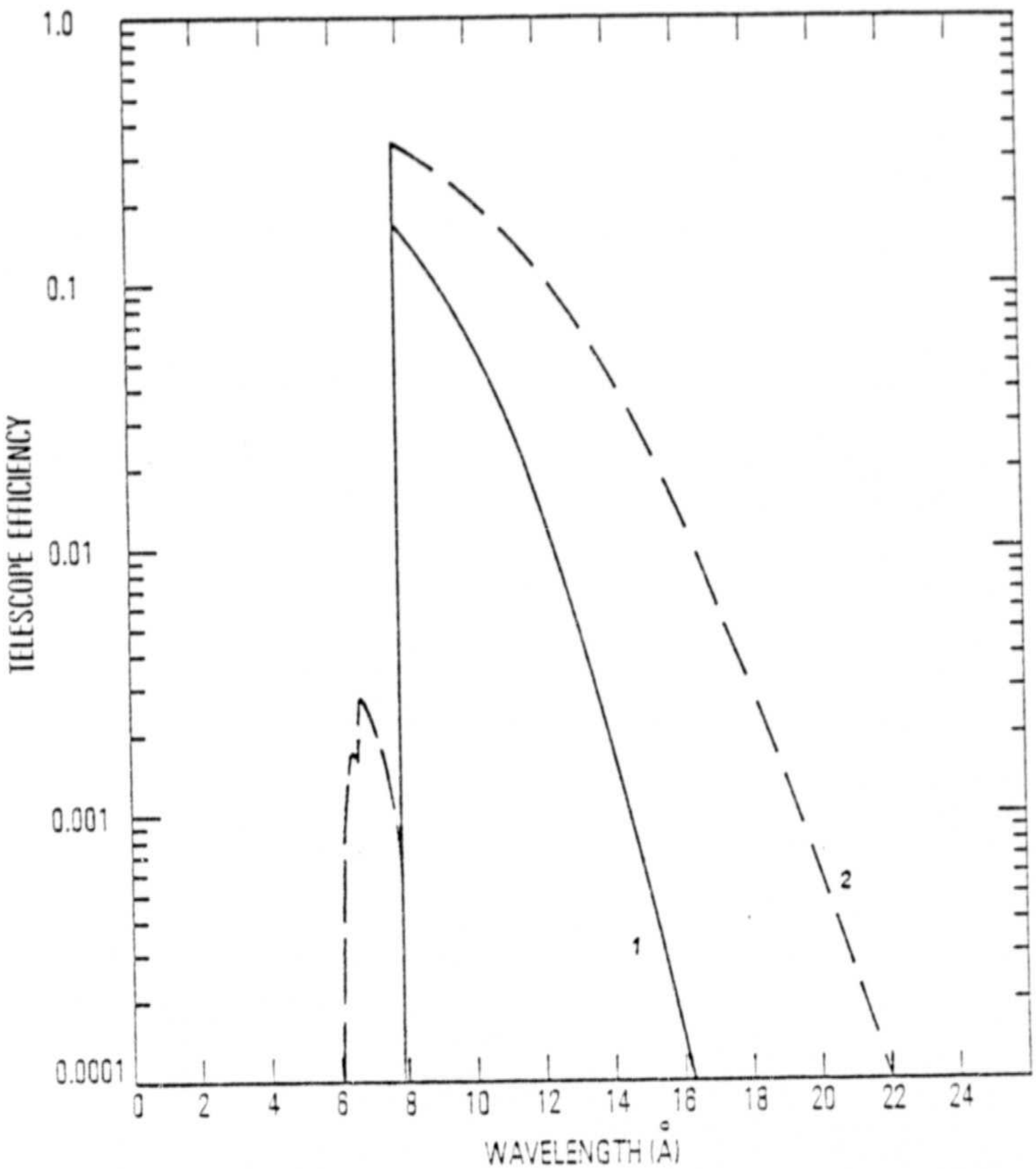


FIGURE 1. PRODUCT OF FILTER TRANSMISSION AND TELESCOPE EFFICIENCY IN THE 0 TO 24 Å REGION - FILTERS 1 AND 2

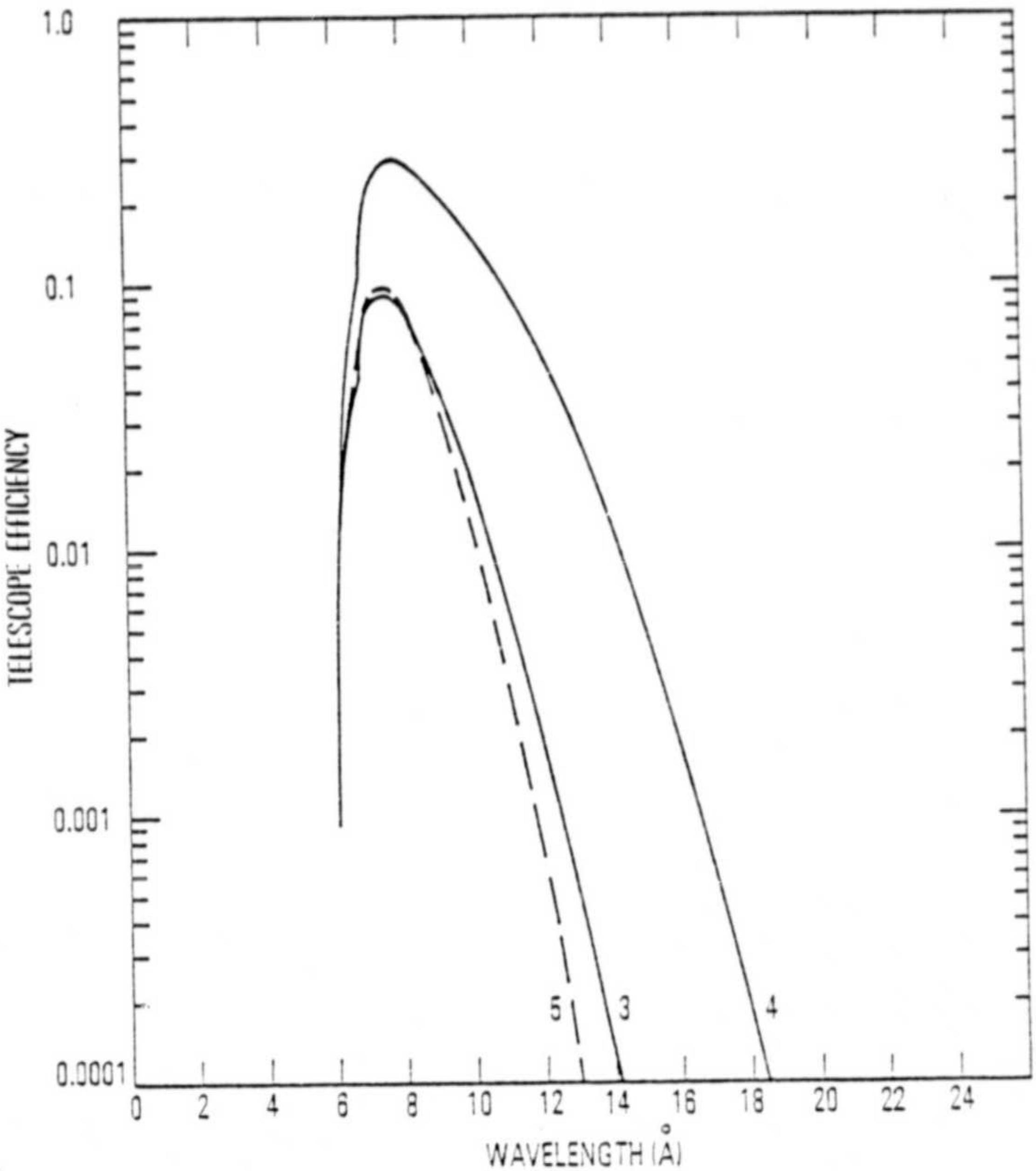


FIGURE 2. PRODUCT OF FILTER TRANSMISSION AND TELESCOPE EFFICIENCY IN THE 0 TO 24-Å REGION - FILTERS 3, 4, AND 5

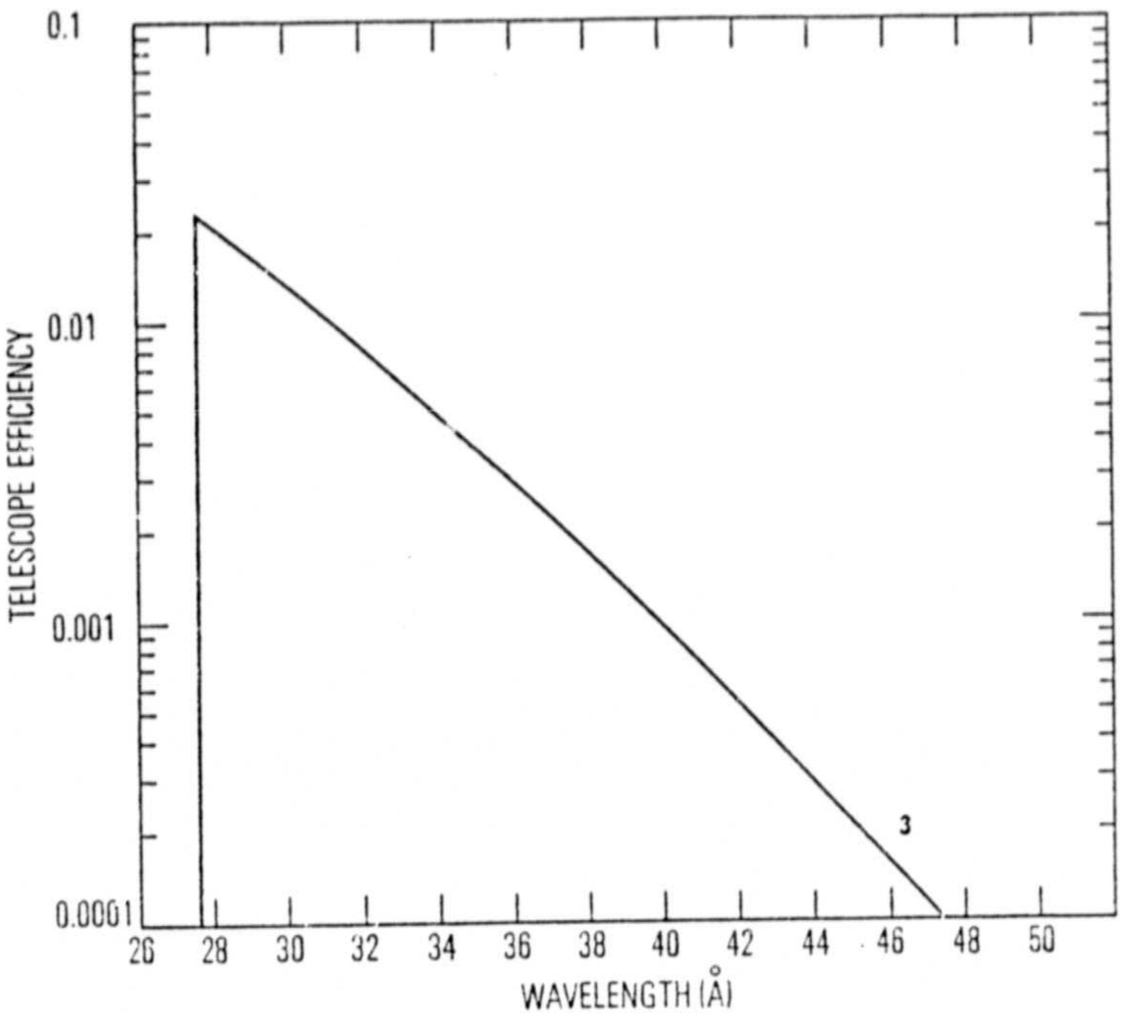


FIGURE 3. PRODUCT OF FILTER TRANSMISSION AND TELESCOPE EFFICIENCY IN THE 26 TO 50-Å REGION - FILTER 3

TABLE 3. NOMINAL EXPOSURE TIMES FOR S-056 X-RAY PHOTOGRAPHS, IN SECONDS

MODE	FILTERS 1	2	3	4	5	6
Patrol Short	26	9	15	17	16.5	0.25
Patrol Normal	88	30	50	57	54	1
Patrol Long	287	97	161	184	175	2
Active (1, 2, or 3) Short	1.5	N/A	1.5	N/A	1.25	N/A
Active (1, 2, or 3) Normal	4.5	N/A	4.5	N/A	4	N/A
Active (1, 2, or 3) Long	15	N/A	15.25	N/A	14.5	N/A

In the Patrol mode, used for routine observations, the camera was cycled once through each of the six filters for a total of six frames. The total time required for the sequence was approximately 1.8 min for Short (PS), 5 min for Normal (PN), and 15.5 min for Long (PL) exposures.

The Active modes were used for studying bright regions that were evolving rapidly. In these modes, the camera cycled through Filters 1, 3, and 5 in rapid succession with the cycles being repeated a number of times and over a period of time depending on which of the submodes was chosen. The Active 1 mode required approximately 5 min for a complete sequence containing either 33 Short (A1S), 36 Normal (A1N), or 15 Long (A1L) exposures. The Active 2 mode (A2S, A2N, or A2L) required approximately 25 min for a complete sequence of 60 frames (20 at each of the three filters). The Active 3 mode (A3S, A3N, or A3L) required approximately 60 min for a complete sequence of 18 frames (six at each of the three filters). In the Active 2 and 3 modes, the number of frames was the same for all choices of exposure times (Short, Normal, or Long).

The Auto mode (AUS, AUN, or AUL), used for flares or other transient phenomena, consisted of an Active 1 sequence, a 1-min delay, an Active 2 sequence, a 10-min delay, and an Active 3 sequence. However, the astronaut would often reinitiate the Auto mode several times rather than allow it to complete its prescribed exposure sequence to obtain more photographs during the flare.

The Single Frame mode (SFS, SFN, or SFL) allowed the astronaut to select a particular filter to obtain a single photograph. The exposure time was the same as that filter would have had in the Patrol mode.

An additional mode, called the Super Long mode (S^L), was devised after the first manned mission to allow exposures of arbitrary length to be made. This mode was usually effected by the astronaut selecting the desired filter and the Single Frame mode (although other modes could be used), initiating the camera operation, turning off the camera power while the shutter was open, waiting the desired length of time, turning on the power, and terminating the operation. The Super Long frames are easily identified by the fact that the data block light array is split into two sections with the exposure stop time information separated from the rest of the array. Each Super Long frame usually contains a primary image of long duration and a secondary image exposed just before termination of the operation. Sometimes there is more than one secondary image.

2.3 FILMS AND CALIBRATION

Five rolls (or loads) of film were exposed during the three manned Skylab missions - four of black-and-white film and one of color reversal film. These rolls of film are referred to as flight film, originals, or first-generation film. Some information on the usage of the film is given in Table 4.

The black-and-white film was Kodak SO-212, a specially developed film with emulsion similar to Kodak Panatomic-X aerial film Type 3400 but without the protective gelatin overcoat and with a Rem-Jet anti-static backing. The color film was Kodak SO-242, an aerial color reversal film with slightly better resolution but slower speed than SO-212.

TABLE 4. S-056 FILM USAGE

MISSION	LOAD	FILM TYPE	DATES	DAY OF YEAR	FRAMES USED
SL2	1	SO-212 (B&W)	29 May 1973 - 18 Jun 1973	149 to 169	3,998
SL3	2	SO-212 (B&W)	07 Aug 1973 - 24 Aug 1973	219 to 236	5,653
	3	SO-212 (B&W)	24 Aug 1973 - 21 Sep 1973	236 to 264	5,797
SL4	5	SO-242 (Color)	26 Nov 1973 - 25 Dec 1973	330 to 359	5,029
	4	SO-212 (B&W)	26 Dec 1973 - 03 Feb 1974	360 to 34	6,713
				TOTAL	27,190

One advantage of the SO-242 is that it shows spectral sensitivity to X-rays. Due to selective filtration by the three emulsion layers, X-rays of different wavelengths appear as different colors on the developed film; thus it may be possible to extract spectral information by color densitometry of color copies.

Copies have been prepared of the original film for submission to the NSSDC and for routine use, including densitometry. The film used for second-generation copies of the black-and-white film, Loads 1 through 4, was Kodak Type 5235, a panchromatic separation film. To best reproduce the large dynamic range on the originals (with densities up to almost 4.0), two copies - a high exposure and a low exposure copy - were required to show both bright and faint X-ray features. These two different exposure copies are therefore known as bright feature (or highlight) and faint feature versions. The second-generation copies are positives and are the ones that have been sent to the NSSDC.

Black-and-white copies have been made of the color film, Load 5, for submission to the NSSDC. Because the flight or first-generation film was a color reversal film, the second generation black-and-white copies are negative copies. Again, both high- and low-exposure versions were made. The film was Kodak Type 2402, a Plus-X aerographic film with a panchromatic emulsion having extended red sensitivity. Third-generation positive copies were then made on Kodak Type 5366, a duplicating positive film. The third-generation copies were normally exposed copies of each of the high- and low-exposure versions of the second-generation films. It is these black-and-white positive third-generation copies, in both the highlight (or bright feature) and faint feature versions, that have been sent to the NSSDC.

For calibration, each load of film contains sets of sensitometric exposures at both the beginning and the end of the film. The beginning of the film is known as the "Heads", while the end is known as the "Tails". The order of occurrence of the solar images goes from Heads to Tails; i.e., the first or earliest images are closest to the Heads end and the last or latest exposures are closest to the Tails end. To allow one to verify the orientation of any one film and to find the "standard" sensitometry set as described later, Tables 5 through 9 identify each set for each load, showing the order in which they are present and giving additional information about each set. The appearance of a typical step for each type of sensitometry is illustrated in Figure 4.

The film calibration information is summarized in Table 10, which relates the exposure in photon cm^{-2} to step number in a selected "standard" sensitometry set for each load of film. Note that the use of the table does not depend on the particular copy of a load of film that is being used.

The standard sensitometry sets are all X-ray sets produced by Sperry Support Services and can be found with the aid of Tables 5 through 9. Set 106 on Load 1 is the fourth set from the Heads end of the film; it is surrounded by the shadows of two trapezoidal pieces of tape on the flight film. Set 047-I on Load 2 is the fifth set from the Heads end of the film and is the first X-ray set on the Heads end. Set 048-I on Load 3 is also the fifth set from the Heads end and the first X-ray set on the film. Set 256 on Load 4 is the first set immediately following the two JSC white light photographic wedges which follow the solar images

TABLE 5. LOAD 1, IDENTIFICATION OF SENSITOMETRY SETS

ORIGIN OF SENSITOMETRY SET	TYPE OF SENSITOMETRY	PRE OR POST FLIGHT	SOURCE OR λ(A)	SET NO.	END OF SET WITH HIGH EXPOSURES	NUMBER OF STEPS (INTENDED OR ACTUAL)	REMARKS, STEP SIZE, OTHER FEATURES ON FILM
↑ HEADS END							
Sperry	X-Ray	Post	Ti	109	H	21	Each step 5/16-in. wide (along film), 1 1/2 in. from center to center
Sperry	X-Ray	Post	Ti	108	H	22	Same as Set 109
Sperry	X-Ray	Post	Al	107	H	21	Same as Set 109
							Trapezoidal piece of tape on flight film
Sperry	X-Ray	Post	Al	106	H	21	Same as Set 109
							Trapezoidal piece of tape on flight film
							~1 1/4-in.-wide gate (highly exposed)
Sperry	Visible	Post	6400		T	21	Each step 3/8 to 1/2 in. wide, 5/8 in. from center to center
Sperry	Visible	Post	5200		T	21	Same as λ6400
Sperry	Visible	Post	4000		T	21	Same as λ6400
							1-in.-wide gate (highly exposed)
Sperry	UV	Post	2600		T	21	Same as λ6400
Aerospace	X-Ray	Post	Al		T	28	
Aerospace	X-Ray	Post	Cu		T	15	
							15 3/4-in. highly exposed section
JSC	Photo	Pre	W.L.	1	T		
JSC	Photo	Pre	W.L.	2	T		Tick mark tenth step from Tails
Sperry	UV	Pre	2600		H	21	Each step 3/8 to 7/16 in. wide, 5/8 in. from center to center
Sperry	Visible	Pre	4000		H	21	Same as λ2600
Sperry	Visible	Pre	5200		H	21	Same as λ2600
Sperry	Visible	Pre	6400		H	21	Same as λ2600
Sperry	X-Ray	Pre	Al	1	T	27	Each step 5/16 in. wide, 1 1/2 in. from center to center; some overlapping steps
Sperry	X-Ray	Pre	Ti	2	T	24	Same step size and spacing as Set 1
Sperry	X-Ray	Pre	Al	3	T	24	Same as Set 2
Sperry	X-Ray	Pre	Ti	4	T	23	Same as Set 2
SOLAR IMAGES							
JSC	Photo	Post	W.L.	3	T		
JSC	Photo	Post	W.L.	4	T		
↓ TAILS END							

H = Heads; T = Tails; W.L. = White Light; UV = Ultraviolet Light; Photo = Photographic

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 6. LOAD 2, IDENTIFICATION OF SENSITOMETRY SETS

ORIGIN OF SENSITOMETRY SET	TYPE OF SENSITOMETRY	PRE OR POST FLIGHT	SOURCE OR λ(A)	SET NO.	END OF SET WITH HIGH EXPOSURES	NUMBER OF STEPS (INTENDED OR ACTUAL)	REMARKS, STEP SIZE, OTHER FEATURES ON FILM
↑ HEADS END							
Sperry	UV	Pre	2600		H	21	Each step 3/8 to 7/16 in. wide, 5/8 in. from center to center
							1-in.-wide gate (highly exposed)
Sperry	Visible	Pre	4000		H	21	Same as λ2600
Sperry	Visible	Pre	5200		H	21	Same as λ2600
Sperry	Visible	Pre	6400		H	21	Same as λ2600
							1 3/8-in.- wide gate (?), 1 1/2-in.- wide gate (?)
Sperry	X-Ray	Pre	Al	047-I	T	21	Each step 5/16 in. wide, 1 1/2 in. from center to center
Sperry	X-Ray	Pre	Al	047-II	T	21	Same as Set 047-I
							6-in. highly exposed section
JSC	Photo	Pre	W.L.	1	T		
JSC	Photo	Pre	W.L.	2	T		
SOLAR IMAGES							
JSC	Photo	Post	W.L	3	T		
JSC	Photo	Post	W.L.	4	T		
							1/2-in. splice, 1-in.-wide gate
Sperry	Visible	Post	6400		T	21	Each step 3/8 to 1/2 in. wide, 5/8 in. from center to center
Sperry	Visible	Post	5200		T	21	Same as λ6400
Sperry	Visible	Post	4000		T	21	Same as λ6400
Sperry						1	Step is centered in 1-in.-wide, lightly exposed section (gate ?)
Sperry	UV	Post	2600		T	21	Same as λ6400
							1-in.-wide gate, ~3 1/2-in. highly exposed section
Sperry	X-Ray	Post	Ti	165			Messed up, steps superimposed
Sperry	X-Ray	Post	Al	164	H	22	Many touching or overlapping steps, close to Set 165
Sperry	X-Ray	Post	Ti	163	H	21	Each step 5/16 in. wide, 19/32 in. normal center to center
Sperry	X-Ray	Post	Al	162	H	21	Same as Set 163
							12 in. long, ~10 1/2-in.-long highly exposed sections
Aerospace	X-Ray	Post			H	2	
Aerospace	X-Ray	Post	Al		H	17	
Aerospace	X-Ray	Post				1	Very faint
Aerospace	X-Ray	Post			H	17	
Aerospace	X-Ray	Post			T	2	
↓ TAILS END							

TABLE 7. LOAD 3, IDENTIFICATION OF SENSITOMETRY SETS

ORIGIN OF SENSITOMETRY SET	TYPE OF SENSITOMETRY	PRE OR POST FLIGHT	SOURCE OR λ(A)	SET NO.	END OF SET WITH HIGH EXPOSURES	NUMBER OF STEPS (INTENDED OR ACTUAL)	REMARKS, STEP SIZE, OTHER FEATURES ON FILM
↑ HEADS END							
Sperry	UV	Pre	2600		H	21	Each step 3/8 to 1/16 in. wide, 5/8 in. from center to center
							1-in.-wide gate (highly exposed)
Sperry	Visible	Pre	4000		H	21	Same as λ2600
Sperry	Visible	Pre	5200		H	21	Same as λ2600
Sperry	Visible	Pre	6400		H	21	Same as λ2600
							1 1/2-in.-wide gate (?)
Sperry	X-Ray	Pre	Al	048-I	T	22	Each step 5/16 in. wide, 1 1/2 in. from center to center
Sperry	X-Ray	Pre	Al	048-II	T	20	Same as Set 048-I
							~2 1/4-in. highly exposed section, 1/2-in. splice
JSC	Photo	Pre	W.L.	1	T		
JSC	Photo	Pre	W.L.	2	T		
SOLAR IMAGES							
JSC	Photo	Post	W.L.	3	T		
JSC	Photo	Post	W.L.	4	T		
							1/2-in.-wide splice, 1-in.-wide gate
Sperry	X-Ray	Post	Al	166	T	21	Each step 5/16 in. wide, 5/8 in. normal from center to center, many steps touching
Sperry	X-Ray	Post	Ti	167	T	9	Same step size, normal spacing as Set 166
							1-in.-wide gate
Sperry	UV	Post	2600		H	21	Each step 3/8 to 7/16 in. wide, 5/8 in. total spacing
Sperry		Post				1	
Sperry	Visible	Post	4000		H	21	Same as λ2600
Sperry	Visible	Post	5200		H	21	Same as λ2600
Sperry	Visible	Post	6400		H	21	Same as λ2600
							1-in.-wide gate, 1/2-in. splice, 1/2-in. splice
Aerospace	X-Ray	Post					Messed up, steps overlapping
↓ TAILS END							

TABLE 8. LOAD 4, IDENTIFICATION OF SENSITOMETRY SETS

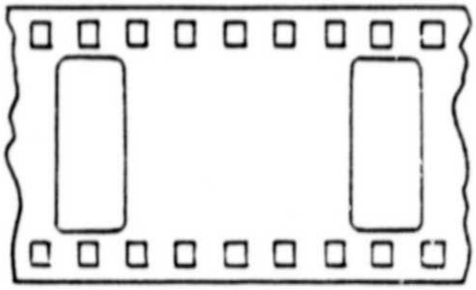
ORIGIN OF SENSITOMETRY SET	TYPE OF SENSITOMETRY	PRE OR POST FLIGHT	SOURCE OR λ(A)	SET NO.	END OF SET WITH HIGH EXPOSURES	NUMBER OF STEPS (INTENDED OR ACTUAL)	REMARKS, STEP SIZE, OTHER FEATURES ON FILM
↑ HEADS END							
Sperry	UV	Pre	2600		H	21	Each step 3/8 to 7/16 in. wide, 5/8 in. from center to center
							~1 1/8-in.-wide gate (?) (highly exposed)
Sperry	Visible	Pre	4000		H	21	Same as λ2600
Sperry	Visible	Pre	5200		H	21	Same as λ2600
Sperry	Visible	Pre	6400		H	21	Same as λ2600
							~2-in.-wide, highly exposed section, 1 7/8-in.-wide gate (?)
Sperry	X-Ray	Pre	Al	045-I	T	21	Each step 5/16 in. wide, 1 1/2 in. from center to center
Sperry	X-Ray	Pre	Al	045-II	T	21	Same as Set 045-I
							~7-in. highly exposed section
JSC	Photo	Pre	W.L	1	T		
JSC	Photo	Pre	W.L.	2	T		
SOLAR IMAGES							
JSC	Photo	Post	W.L.	3	T		
JSC	Photo	Post	W.L.	4	T		
							1/2-in.-wide splice, 6 1/2-in. highly exposed section, 1-in.-wide gate
Sperry	X-Ray	Post	Al	256	T	22	Each step 5/16 in. wide, 1 1/2 in. from center to center
Sperry	X-Ray	Post	Cu	257	T	22	Same as Set 256
Sperry	X-Ray	Post	Ti	258	T	22	Same as Set 256
							1 1/4-in.-wide gate
Sperry	UV	Post	2600		H	21	Each step 3/8 to 7/16 in. wide, 5/8 in. from center to center
Sperry	Visible	Post	4000		H	13	Same as λ2600
Sperry	Visible	Post	4000		H	21	Same as λ2600
Sperry	Visible	Post	5200		H	21	Same as λ2600
Sperry	Visible	Post	6400		H	21	Same as λ2600
							1-in.- wide gate; "Marshall Sensi" 1/2-in. splice; "Aerospace Sensi"
Aerospace	X-Ray	Post	Cu	3	H	17	
Aerospace	X-Ray	Post	Al	2	H	17	Two lowest exposure steps overlap
Aerospace	X-Ray	Post	Al	1	H	16	
↓ TAILS END							

TABLE 9. LOAD 5, IDENTIFICATION OF SENSITOMETRY SETS

ORIGIN OF SENSITOMETRY SET	TYPE OF SENSITOMETRY	PRE OR POST FLIGHT	SOURCE OR λ(A)	SET NO.	END OF SET WITH HIGH EXPOSURES	NUMBER OF STEPS (INTENDED OR ACTUAL)	REMARKS, STEP SIZE, OTHER FEATURES ON FILM
↑ HEADS END							
JSC	Photo	Pre	W.L.	1	T		
JSC	Photo	Pre	W.L.	2	T		
SOLAR IMAGES							
JSC	Photo	Post	W.L.	3	T		
JSC	Photo	Post	W.L.	4	T		
							1/2-in.-wide splice, "Marshall Sensi", highly exposed mark (made by tape on flight film), 1-in.-wide gate
Sperry	Visible	Post	6400		T	21	Each step 3/8 to 7/16 in. wide, 5/8 in. from center to center
Sperry	Visible	Post	5200		T	21	Same as λ6400
Sperry	Visible	Post	4000		T	21	Same as λ6400
Sperry	UV	Post	2600		T	21	Same as λ6400
							1-in.-wide gate
Sperry	X-Ray	Post	Ti	255	H	22	Each step 5/16 in. wide, 1 1/2 in. from center to center
Sperry	X-Ray	Post	Cu	254	H	22	Same as Set 255
Sperry	X-Ray	Post	Al	253	H	21	Same as Set 255
							1-in.-wide gate, 10-in. highly exposed section, 1/2-in.-wide splice, "Aerospace Sensi"
Aerospace	X-Ray	Post	Al	1	T	21	
Aerospace	X-Ray	Post	Cu	2	T	18	
Aerospace	X-Ray	Post	Cu	3	T	13	
							2 1/2-in.-long, medium exposed section, 1/2-in.-wide splice, "227"
Sperry	X-Ray	Test	Al	227	H	12	
							1/2-in.-wide splice, "226"
Sperry	X-Ray	Test	Al	226	H	12	
↓ TAILS END							

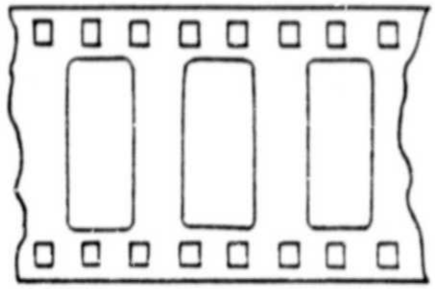
Test = Sensitometry set made on film which did not fly on Skylab.

ORIGINAL PAGE IS OF POOR QUALITY



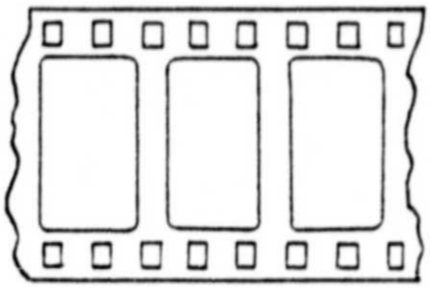
SPERRY X-RAY

LOADS 1, 4, 5 - ALL
LOADS 2, 3 - PREFLIGHT ONLY



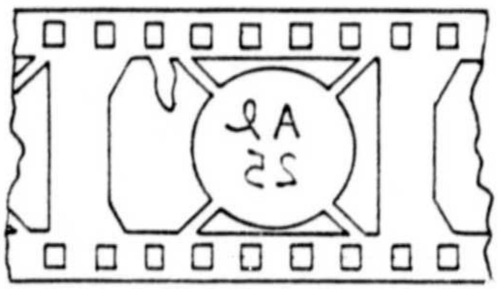
SPERRY X-RAY

LOADS 2, 3 - POSTFLIGHT ONLY



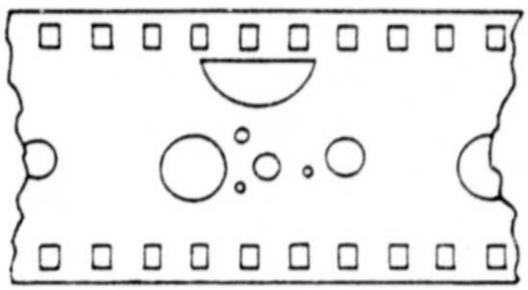
SPERRY VISIBLE, UV

ALL LOADS



AEROSPACE X-RAY

LOAD 1



AEROSPACE X-RAY

LOADS 2, 3, 4, 5

EMULSION IS DOWN ON FLIGHT FILM, UP ON SECOND-GENERATION COPY. TAILS IS TO THE RIGHT IN ALL CASES EXCEPT AEROSPACE X-RAY LOAD 4 WHERE HEADS IS TO THE RIGHT.

FIGURE 4. APPEARANCE OF TYPICAL SENSITOMETRY SETS

TABLE 10. S-056 FILM CALIBRATION

STEP NO. FROM HIGH EXPOSURE END	EXPOSURE (photon cm^{-2})				
	LOAD 1 SET 106	LOAD 2 SET 047-I	LOAD 3 SET 048-I	LOAD 4 SET 256	LOAD 5 SET 253
	↑ HEADS	↑ TAILS	↑ TAILS	↑ TAILS	↑ HEADS
1	5.97(10)	3.05(10)	4.06(10)	3.31(11)	1.30(11)
2	2.99(10)	1.81(10)	2.10(10)	1.66(11)	6.49(10)
3	1.49(10)	8.99(9)	9.62(9)	8.28(10)	3.24(10)
4	7.46(9)	4.12(9)	4.79(9)	4.14(10)	1.62(10)
5	3.76(9)	2.15(9)	2.40(9)	2.07(10)	8.11(9)
6	1.81(9)	1.05(9)	1.15(9)	1.04(10)	4.06(9)
7	1.38(9)	7.38(8)	8.26(8)	4.97(9)	2.87(9)
8	9.29(8)	5.22(8)	5.89(8)	3.64(9)	1.97(9)
9	6.53(8)	3.76(8)	4.09(8)	2.50(9)	1.39(9)
10	4.65(8)	2.62(8)	2.91(8)	1.72(9)	9.93(8)
11	3.27(8)	1.85(8)	2.06(8)	1.22(9)	6.98(8)
12	2.32(8)	1.31(8)	1.46(8)	8.55(8)	4.97(8)
13	1.67(8)	9.40(7)	1.05(8)	6.08(8)	3.56(8)
14	1.16(8)	6.53(7)	7.31(7)	4.40(8)	2.48(8)
15	7.98(7)	4.49(7)	5.04(7)	3.10(8)	1.71(8)
16	5.81(7)	3.27(7)	3.66(7)	2.15(8)	1.24(8)
17	4.36(7)	2.92(7)	2.74(7)	1.57(8)	9.31(7)
18	2.90(7)	2.60(7)	1.83(7)	1.17(8)	6.21(7)
19	2.18(7)	1.22(7)	1.37(7)	7.82(7)	4.66(7)
20	1.45(7)	8.17(6)	9.14(6)	5.87(7)	3.10(7)
21	7.26(6)	4.08(6)	9.14(6)	3.91(7)	1.55(7)
22			4.57(6)	1.95(7)	
	↓ TAILS	↓ HEADS	↓ HEADS	↓ HEADS	↓ TAILS

on the Tails end of the film. Set 253 on Load 5 is the Sperry X-ray set that is immediately in front of the Aerospace sensitometry on the Tails end of the film.

The step numbers within each set begin at the end with the highest exposure steps; i.e., the steps that are most different from the background. The central portion of each step should be used for density measurements.

2.4 OBSERVATIONAL DATA ON FILM

The S-056 X-ray telescope made over 27,000 photographs (filterheliograms) of the Sun during the Skylab mission. Each frame normally consists of an image of the Sun plus the image of the data block light system used to identify the instrumental parameters associated with that exposure. Often the solar image will show only active regions; the limb and the orientation are not always obvious. However, the visible light images (Filter 6) show the entire disk and are often an aid in identifying when the telescope was in a Patrol mode and thus the sequencing of all of the filters in the Patrol mode.

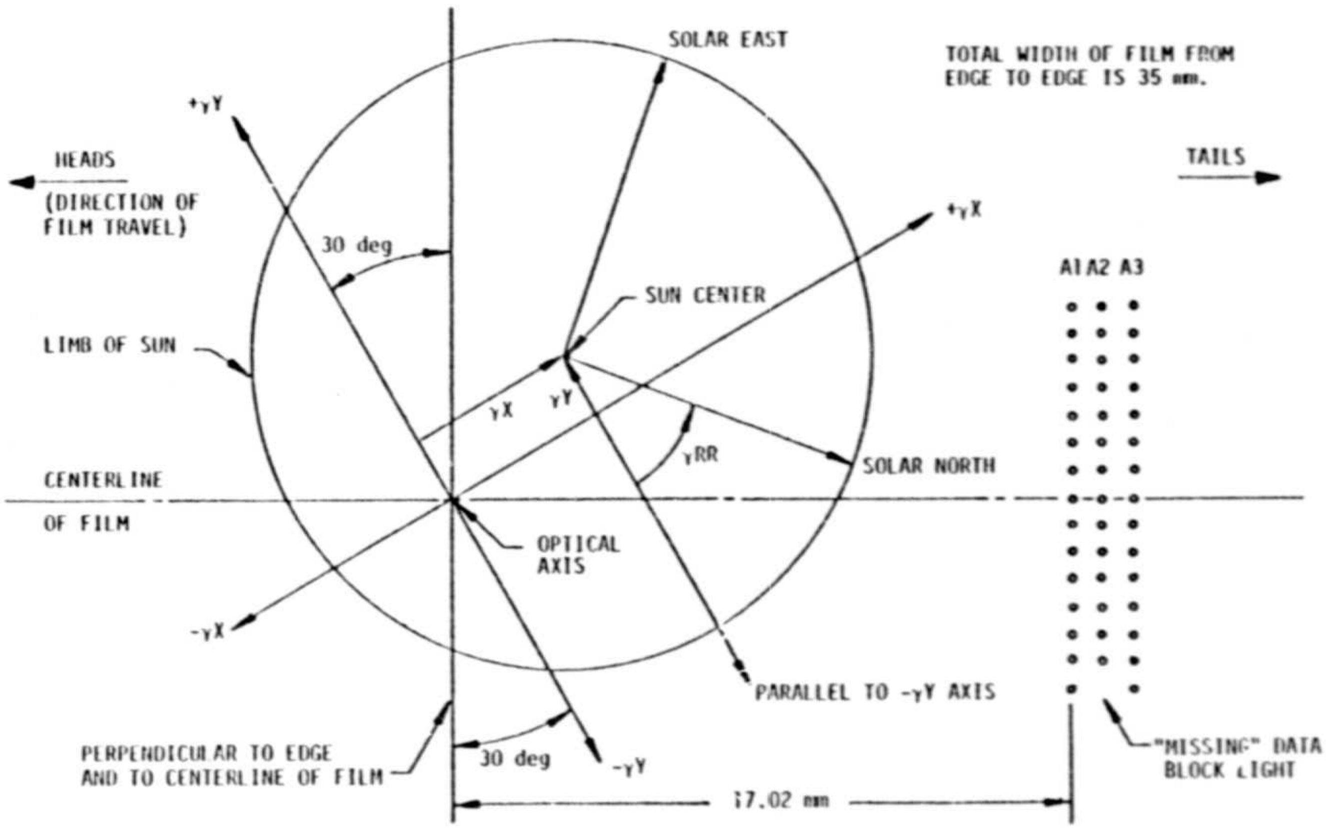
The data block images for all S-056 frames have been visually read and compiled in the "S-056 Frame Listing", a copy of which has been submitted to the NSSDC. In addition, the operating modes have been listed in the "ATM Mission Operation Log", provided by Ball Brothers Research Corporation, which identifies ATM experiment operations as a function of time during the Skylab missions, as well as the γRR, γX, and γY reconstructed values. Because the Super-Long exposures were not made in a normal manner, only their start times appear in the BBRC publication. However, the "Atlas of Skylab ATM/S-056 Super-Long Exposures and Stepped-Image Frames" (NASA TMX-64992) contains a listing of the S-056 Super-Long mode operations, numbering 552, that were performed during the last two manned missions and gives their exposure times.

Figure 5 illustrates the S-056 film format for normal images (when north is up, east is to the left). Therefore, to use the figure one should have the emulsion down on the flight film (also called first generation) or on third-generation copies; the emulsion should be up on second-generation copies. Note that the position of the "missing" data block light (which may have to be determined from other nearby frames) can sometimes be helpful in orienting the film. The location of the telescope optical axis on the film is 17.02 mm from the A1 column of data block lights for that frame and is on the centerline of the film.

ATM experiment pointing was achieved through the use of the Experiment Pointing Control, which used the Fine Sun Sensor as reference and fine pointed the experiment canister with an accuracy and stability of better than 2.5 arc sec. The X-Y pointing (given by the angles γX and γY) was accomplished by means of actuators at the canister gimbal pivots and the canister roll positioning (given by the angle γRR) by the roll position mechanism; both were operated from the ATM Control and Display panel. The desired coordinates were chosen as follows: The ATM planning group, consisting of representatives from each experiment, NOAA, and NASA/Johnson Space Center Flight Control Division, determined the features and regions of interest that the astronauts were to observe. A pointing grid was overlaid on an appropriate Hα photograph in the desired orientation, and the values of the coordinates γRR, γX, and γY were thus determined.

The values of γRR, γX, and γY as a function of time are tabulated in the BBRC "ATM Mission Operation Log". γRR is given in arc minutes; γX and γY are given in arc seconds. The accuracy of the roll angles reconstructed from computer records has been questioned because of disagreements with other determinations, such as those based on star fields observed by the S-052 White Light Coronagraph. Further discussions of this question and the ATM Experiment Pointing System in general can be found in technical reports published by Ball Brothers Research Corporation.

EMULSION DOWN ON FLIGHT FILM (FIRST GENERATION) AND THIRD-GENERATION COPY.
EMULSION UP ON SECOND-GENERATION COPY.



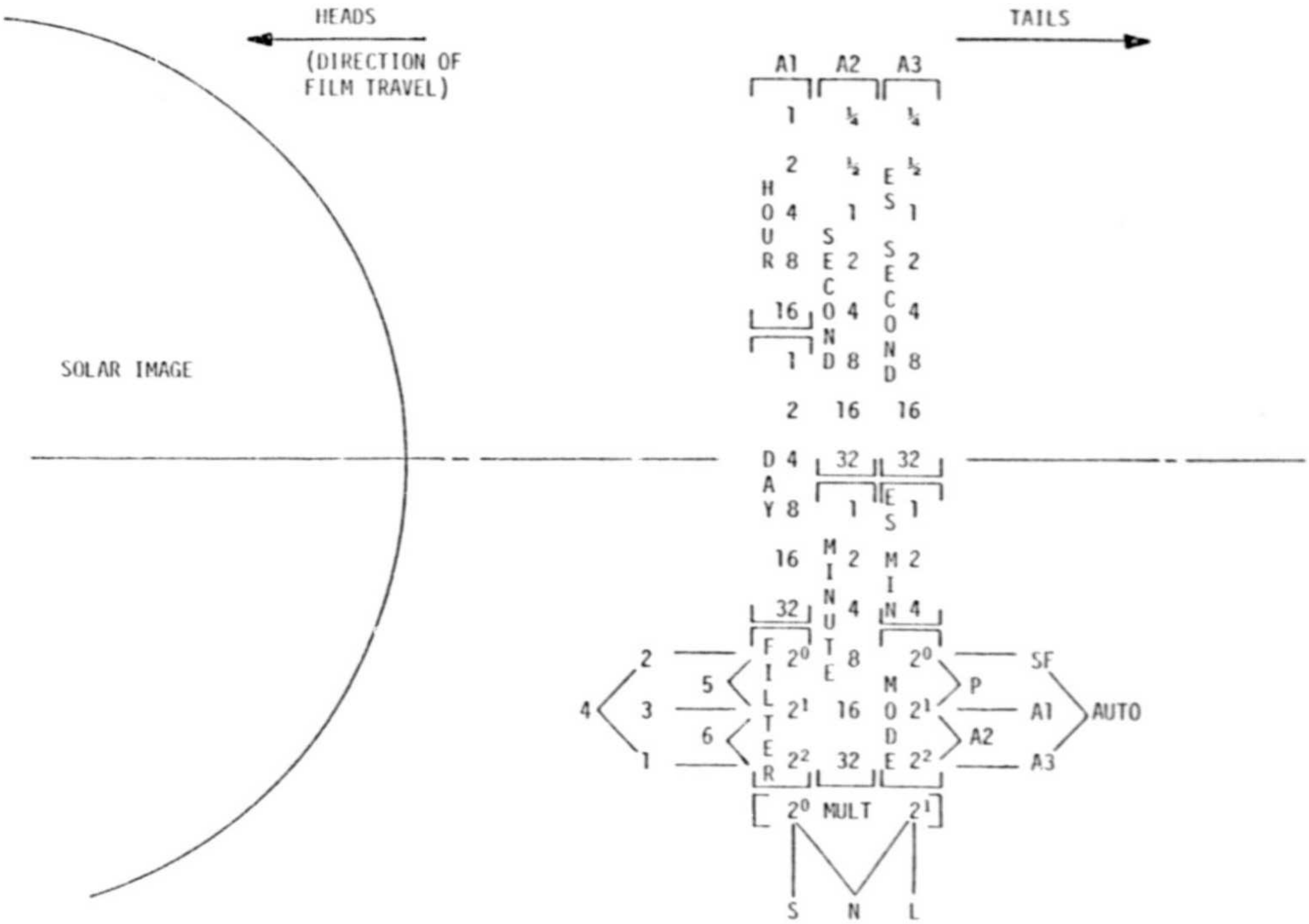
THE COORDINATES γX, γY, AND γRR ARE POSITIVE IN THE DIRECTION OF THE ARROWS. THE VALUES USED TO CONSTRUCT THE EXAMPLE SHOWN IN THE FIGURE ARE γX = +500 (ARC SEC), γY = +200 (ARC SEC), AND γRR = +2,400 (ARC MIN). NOTE THAT FOR γX AND γY, 100 ARC SEC = 0.923 mm.

FIGURE 5. FORMAT OF S-056 FRAME

In general, investigators using the S-056 film data have used computer-assisted visual determinations of solar north instead of the tabulated roll angles, especially for work requiring ac... ate coregistration of images.

To find the center of the Sun and the direction of solar north on an S-056 frame from given values of γX, γY, and γRR, one should proceed as follows (Figure 5). First, find the center of the Sun by converting γX and γY from arc seconds to microns or millimeters using the plate scale of 9.23 μm/arc sec or 9.23×10^{-3} mm/arc sec and then shift by those amounts along the appropriate directions as shown in the figure. Then find solar north by going counter-clockwise, for positive γRR in arc minutes, from the negative γY direction. The offset of the γY axis by 30 deg from the perpendicular to the edge of the film is caused by the orientation of the film magazine within the S-056 instrument and the ATM canister.

To uniquely describe each exposure on the film, an intricate data block optical system, consisting of 44 subminiature lamps whose images were projected onto the film, was provided. These data block images identified the camera mode of operation, exposure multiplier (i.e., whether the exposure was Short, Normal, or Long), filter, exposure start time, and exposure stop time. Figure 6 illustrates the data block configuration and deciphers the code for the various times, modes, filters, and multipliers indicated by the appropriately lit data block lights. The middle column has only 14 lights instead of 15; noting the position of the missing step is often an aid in orienting the data block lights and the solar image. While time of exposure start and stop was reckoned from the onboard spacecraft clock, the individual mode exposures were controlled internally by the experiment's Camera/Thermal Control Electronics package. The exposure start time was encoded on the film in the A1 and A2 columns when the astronaut initiated the operation. Similarly, the exposure stop time (in minutes and seconds only) was encoded in the A3 column when the operation was terminated. When reading the Exposure



EMULSION IS DOWN ON FLIGHT FILM. THERE IS NO DATA BLOCK LIGHT IN THE BOTTOM ROW OF COLUMN "A2".

FIGURE 6. DATA BLOCK CONFIGURATION

Stop (ES) data lights, one must remember that the code identifies only the minutes and seconds of the exposure when it was terminated, not the exposure time. Exposure time or duration is directly calculated as the difference between exposure start time and exposure stop time.

The "Day" information (Figure 6) refers to the spacecraft "clock day", which recycled every 64 days. Table 11 correlates the Day-Of-Year (DOY) with the Date (DATE), Mission Day (MD), and Clock Day (CD) during the Skylab missions and provides additional information such as the periods for which microfilm is available and EVA occurrences.

2.5 QUANTITATIVE ANALYSIS

To convert from density on the film to intensity emitted by the Sun, one should go through the following steps.

Density should be converted to exposure (in photon cm^{-2}) at the film by use of Table 10. The table relates exposure to step number in standard sensitometry sets on the film. The density of each step can be measured in any method with any units desired by the user - microdensitometer measurements, microphotometer readings, scanner gray scale reading, etc.

The exposure should then be divided by the exposure time, t, to yield the photon flux, E/t, (in photon $cm^{-2}\ s^{-1}$) at the film. The exposure time can be obtained from the data block lights for the particular frame, or the nominal values given in Table 3 can be used.

The photon flux should be multiplied by the square of the focal length, f, and divided by the telescope collecting area, A_T, to obtain the photon intensity integrated over the filter bandpass (in photon $cm^{-2}s^{-1}\ sr^{-1}$):

$$\int \eta_n \frac{I_\lambda}{h\nu}\, d\lambda = \frac{f^2}{A_T}\ \frac{E}{t} \quad ,$$

TABLE 11. CORRELATION BETWEEN DATE AND VARIOUS "DAYS", MICROFILM AVAILABILITY FOR 6-HOUR PERIODS, MISSION MILESTONES

DOY	DATE	MD	CD	MICROFILM	REMARKS
132	5/12				
133	5/13				
134	5/14		0		Launch SL1
135	5/15		1		
136	5/16		2		
137	5/17		3		
138	5/18		4		
139	5/19		5		
140	5/20		6		
141	5/21		7		
142	5/22		8		
143	5/23		9		
144	5/24		10		
145	5/25	1	11		Launch SL2
146	5/26	2	12		
147	5/27	3	13		
148	5/28	4	14		
149	5/29	5	15	3 4	
150	5/30	6	16	1 2 3 4	
151	5/31	7	17	1 3 4	
152	6/1	8	18	1 3 4	
153	6/2	9	19	1 3 4	
154	6/3	10	20	1 3 4	
155	6/4	11	21	1 3 4	CALROC
156	6/5	12	22	1 3 4	
157	6/6	13	23	1 3 4	
158	6/7	14	24	1 2 3 4	EVA
159	6/8	15	25	1 3 4	
160	6/9	16	26	1 3 4	
161	6/10	17	27	1 3 4	
162	6/11	18	28	1 3 4	
163	6/12	19	29	1 2 3 4	
164	6/13	20	30	1 2 3 4	
165	6/14	21	31	1 2 3 4	
166	6/15	22	32	1 2 3 4	
167	6/16	23	33	1 2 3 4	
168	6/17	24	34	1 2 3 4	
169	6/18	25	35	1 2 3 4	
170	6/19	26	36		EVA
171	6/20	27	37		
172	6/21	28	38		
173	6/22	29	39		Splashdown SL2
174	6/23		40		
175	6/24		41		
176	6/25		42		
177	6/26		43		
178	6/27		44		
179	6/28		45		
180	6/29		46		
181	6/30		47		Partial Eclipse
182	7/1		48		
183	7/2		49		
184	7/3		50		
185	7/4		51		
186	7/5		52		
187	7/6		53		
188	7/7		54		
189	7/8		55		
190	7/9		56		
191	7/10		57		

TABLE 11 - Continued

DOY	DATE	MD	CD	MICROFILM	REMARKS
192	7/11		58		
193	7/12		59		
194	7/13		60		
195	7/14		61		
196	7/15		62		
197	7/16		63		
198	7/17		0		
199	7/18		1		
200	7/19		2		
201	7/20		3		
202	7/21		4		
203	7/22		5		
204	7/23		6		
205	7/24		7		
206	7/25		8		
207	7/26		9		
208	7/27		10		
209	7/28	1	11	1 2 3	Launch SL3
210	7/29	2	12	1 2 3 4	
211	7/30	3	13	1 3 4	
212	7/31	4	14	1 2 3 4	
213	8/1	5	15	1 3 4	
214	8/2	6	16	1 3 4	
215	8/3	7	17	1 3	
216	8/4	8	18	1 2	
217	8/5	9	19	3 4	
218	8/6	10	20	1 2 3 4	EVA
219	8/7	11	21	1 2 3 4	
220	8/8	12	22	1 2 3 4	
221	8/9	13	23	1 2 3 4	CALROC
222	8/10	14	24	1 2 3 4	
223	8/11	15	25	1 2 3 4	
224	8/12	16	26	1 2 3 4	
225	8/13	17	27	1 2 3 4	
226	8/14	18	28	1 2 3 4	
227	8/15	19	29	1 2 3 4	
228	8/16	20	30	1 2 3 4	
229	8/17	21	31	1 2 3 4	
230	8/18	22	32	1 2 3 4	
231	8/19	23	33	1 2 3 4	
232	8/20	24	34	1 2 3 4	
233	8/21	25	35	1 2 3 4	
234	8/22	26	36	1 2 3 4	
235	8/23	27	37	1 2 3 4	
236	8/24	28	38	1 2 3 4	EVA
237	8/25	29	39	1 2 3 4	
238	8/26	30	40	1 2 3 4	
239	8/27	31	41	1 2 3 4	
240	8/28	32	42	1 2 3 4	
241	8/29	33	43	1 2 3 4	
242	8/30	34	44	1 2 3 4	
243	8/31	35	45	1 2 3 4	
244	9/1	36	46	1 2 3 4	
245	9/2	37	47	1 2 3 4	
246	9/3	38	48	1 2 3 4	
247	9/4	39	49	1 2 3 4	
248	9/5	40	50	1 2 3 4	
249	9/6	41	51	1 2 3 4	
250	9/7	42	52	1 2 3 4	
251	9/8	43	53	1 2 3 4	

TABLE 11 - Continued

DOY	DATE	MD	CD	MICROFILM	REMARKS
252	9/9	44	54	1 2 3 4	
253	9/10	45	55	1 2 3 4	
254	9/11	46	56	1 2 3 4	
255	9/12	47	57	1 2 3 4	
256	9/13	48	58	1 2 3 4	
257	9/14	49	59	1 2 3 4	
258	9/15	50	60	1 2 3 4	
259	9/16	51	61	1 2 3 4	
260	9/17	52	62	1 2 3 4	
261	9/18	53	63	1 2 3 4	
262	9/19	54	0	1 2 3 4	
263	9/20	55	1	1 2 3 4	
264	9/21	56	2	1 2 3 4	
265	9/22	57	3	1 2 3 4	EVA
266	9/23	58	4		
267	9/24	59	5		
268	9/25	60	6		Splashdown SL3
269	9/26		7		
270	9/27		8		
271	9/28		9		
272	9/29		10		
273	9/30		11		
274	10/1		12		
275	10/2		13		
276	10/3		14		
277	10/4		15		
278	10/5		16		
279	10/6		17		
280	10/7		18		
281	10/8		19		
282	10/9		20		
283	10/10		21		
284	10/11		22		
285	10/12		23		
286	10/13		24		
287	10/14		25		
288	10/15		26		
289	10/16		27		
290	10/17		28		
291	10/18		29		
292	10/19		30		
293	10/20		31		
294	10/21		32		
295	10/22		33		
296	10/23		34		
297	10/24		35		
298	10/25		36		
299	10/26		37		
300	10/27		38		
301	10/28		39		
302	10/29		40		
303	10/30		41		
304	10/31		42		
305	11/1		43		
306	11/2		44		
307	11/3		45		
308	11/4		46		
309	11/5		47		

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 11 - Continued

DOY	DATE	MD	CD	MICROFILM	REMARKS
310	11/6		48		
311	11/7		49		
312	11/8		50		
313	11/9		51		
314	11/10		52		
315	11/11		53		
316	11/12		54		
317	11/13		55		
318	11/14		56		
319	11/15		57		
320	11/16	1	58		Launch SL4
321	11/17	2	59		
322	11/18	3	60		
323	11/19	4	61		
324	11/20	5	62		
325	11/21	6	63		
326	11/22	7	0		EVA
327	11/23	8	1		
328	11/24	9	2		
329	11/25	10	3		
330	11/26	11	4	4	
331	11/27	12	5	1 2 3 4	
332	11/28	13	6	1 2 3 4	
333	11/29	14	7	1 2 3 4	
334	11/30	15	8	1 2 3 4	
335	12/1	16	9	1 2 3 4	
336	12/2	17	10	1 2 3 4	
337	12/3	18	11	1 2 3 4	
338	12/4	19	12	1 2 3 4	
339	12/5	20	13	1 2 3 4	
340	12/6	21	14	1 2 3 4	
341	12/7	22	15	1 2 3 4	
342	12/8	23	16	1 2 3 4	
343	12/9	24	17	1 2 3 4	
344	12/10	25	18	1 2 3 4	CALROC
345	12/11	26	19	1 2 3 4	
346	12/12	27	20	1 2 3 4	
347	12/13	28	21	1 2 3 4	
348	12/14	29	22	1 2 3 4	
349	12/15	30	23	1 2 3 4	
350	12/16	31	24	1 2 3 4	
351	12/17	32	25	1 2 3 4	
352	12/18	33	26	1 2 3 4	
353	12/19	34	27	1 2 3 4	
354	12/20	35	28	1 2 3 4	
355	12/21	36	29	1 2 3 4	
356	12/22	37	30	1 2 3 4	
357	12/23	38	31	1 2 3 4	
358	12/24	39	32	1 2 3 4	Partial Eclipse
359	12/25	40	33	1 2 3 4	EVA
360	12/26	41	34	1 2 3 4	
361	12/27	42	35	1 2 3 4	
362	12/28	43	36	1 2 3 4	
363	12/29	44	37	1 2 3 4	EVA
364	12/30	45	38	1 2 3 4	
365	12/31	46	39	1 2 3 4	
1	1/1	47	40	1 2 3 4	
2	1/2	48	41	1 2 3 4	
3	1/3	49	42	1 2 3 4	
4	1/4	50	43	1 2 3 4	

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 11 - Concluded

DOY	DATE	MD	CD	MICROFILM	REMARKS
5	1/5	51	44	1 2 3 4	
6	1/6	52	45	1 2 3 4	
7	1/7	53	46	1 2 3 4	
8	1/8	54	47	1 2 3 4	
9	1/9	55	48	1 2 3 4	
10	1/10	56	49	1 2 3 4	
11	1/11	57	50	1 2 3 4	
12	1/12	58	51	1 2 3 4	
13	1/13	59	52	1 2 3 4	
14	1/14	60	53	1 2 3 4	
15	1/15	61	54	1 2 3 4	
16	1/16	62	55	1 2 3 4	
17	1/17	63	56	1 2 3 4	
18	1/18	64	57	1 2 3 4	
19	1/19	65	58	1 2 3 4	
20	1/20	66	59	1 2 3 4	
21	1/21	67	60	1 2 3 4	
22	1/22	68	61	1 2 3 4	
23	1/23	69	62	1 2 3 4	
24	1/24	70	63	1 2 3 4	
25	1/25	71	0	1 2 3 4	
26	1/26	72	1	1 2 3 4	
27	1/27	73	2	1 2 3 4	
28	1/28	74	3	1 2 3 4	
29	1/29	75	4	1 2 3 4	
30	1/30	76	5	1 2 3 4	
31	1/31	77	6	1 2 3 4	
32	2/1	78	7	1 2 3 4	
33	2/2	79	8	1 2 3 4	
34	2/3	80	9	1 3	EVA
35	2/4	81	10		
36	2/5	82	11	3	
37	2/6	83	12		
38	2/7	84	13		
39	2/8	85	14		Splashdown SL4
40	2/9		15		
41	2/10		16		
42	2/11		17		
43	2/12		18		
44	2/13		19		
45	2/14		20		
46	2/15		21		
47	2/16		22		
48	2/17		23		
49	2/18		24		
50	2/19		25		
51	2/20		26		
52	2/21		27		
53	2/22		28		
54	2/23		29		

where

η_n - filter transmission multiplied by the mirror reflectivities, given in Figures 1 through 3

n - filter number

I_λ - usual specific intensity (or radiance) used in astrophysics (with units erg cm^{-2} s^{-1} sr^{-1} $\mathring{A}^{-1}$).

The focal length and telescope aperture area are given in Table 1.

Although the above procedure is quite straightforward, there are pitfalls to be wary of. First is the use of copies instead of the original flight film. It is extremely difficult to avoid nonuniformity in the copying process. Resolution of small-scale features will also be degraded. Another possible problem is the use of wavelength-invariant characteristic curves where exposure is given in photons rather than energy. The use of such curves may not always be valid, especially at the long wavelengths passed by Filter 3. Other errors can arise from the usual problems associated with photographic photometry: inaccuracies in determining the characteristic curve and errors in measuring density, especially of small features on the film.

3. X-RAY FILTER BANDPASSES

The X-ray filter bandpasses have been given earlier in Table 2; the values are given in angstroms to one decimal place. The definition used there is the spectral region where the product of the filter transmission and the reflectivities of the mirrors exceeds 10^{-3}. Often it is more convenient to use wavelengths rounded off to the nearest angstrom. These values are given in column 3 of Table 12 for the same definition of the bandpass given above. However, that definition causes Filters 2 and 4 to appear too similar. Therefore, it is recommended that the wavelength range where the transmission exceeds 1% of peak transmission be chosen as the definition of the bandpass. The wavelengths corresponding to this definition are given in column 4 of Table 12. The peak transmission for each filter was already given in Table 2.

TABLE 12. S-056 X-RAY FILTER BANDPASSES
(ROUNDED OFF TO NEAREST ANGSTROM)

FILTER	MATERIAL	WAVELENGTH RANGE WHERE TRANSMISSION EXCEEDS 10^{-3} (Å)	WAVELENGTH RANGE WHERE TRANSMISSION EXCEEDS 1% OF PEAK (Å)
1	0.50-mil Aluminum	8 to 15	8 to 14
2	0.25-mil Aluminum	6 to 19	8 to 18
3	0.086-mil Titanium	6 to 13 27 to 40	6 to 13 27 to 40
4	1-mil Beryllium	6 to 17	6 to 16
5	3-mil Beryllium	6 to 12	6 to 12

4. S-056 POINT SPREAD FUNCTION

The best determination currently available of the S-056 Point Spread Function (PSF) is shown in Figure 7 and tabulated in Table 13. The PSF shown is for on-axis images only.

The core of the profile comes from pinhole photographs made at Martin-Marietta in Denver. The pinhole images were scanned at the Johnson Space Center by R. B. Hoover of Marshall Space Flight Center. Most of the photometric reduction was done by W. Henze of Teledyne Brown Engineering, with some work also being done by E. J. Reichmann of MSFC. Part of the photometric work involved generating a characteristic curve for the film. Because no sensitometry was performed on the film when the pinhole images were exposed at Martin-Marietta, the characteristic curve to be used was interpolated from curves for the same emulsion but processed at different temperatures and developing times.

The far wings of the PSF come from limb scans of solar images. The limb scans were made at the Aerospace Corporation and were differentiated there to obtain the line spread function. The line spread function was then "deconvolved" to yield the wings of the PSF. The core and the wings were then matched together to obtain the best fit.

TABLE 13. S-056 POINT SPREAD FUNCTION

RADIUS (arc sec)	POINT SPREAD FUNCTION	RADIUS (arc sec)	POINT SPREAD FUNCTION
0.0	1.0	4.0	8.6(-2)
0.1	9.8(-1)	5.0	4.8(-2)
0.2	9.5(-1)	7.0	1.8(-2)
0.3	8.8(-1)	10.0	8.8(-3)
0.5	7.4(-1)	15.0	4.3(-3)
0.8	5.2(-1)	20.0	3.2(-3)
1.0	4.2(-1)	25.0	2.4(-3)
1.2	3.1(-1)	30.0	1.4(-3)
1.5	1.30(-1)	40.0	3.6(-4)
2.0	1.25(-1)	50.0	8.0(-5)
3.0	1.08(-1)	60.0	1.2(-5)

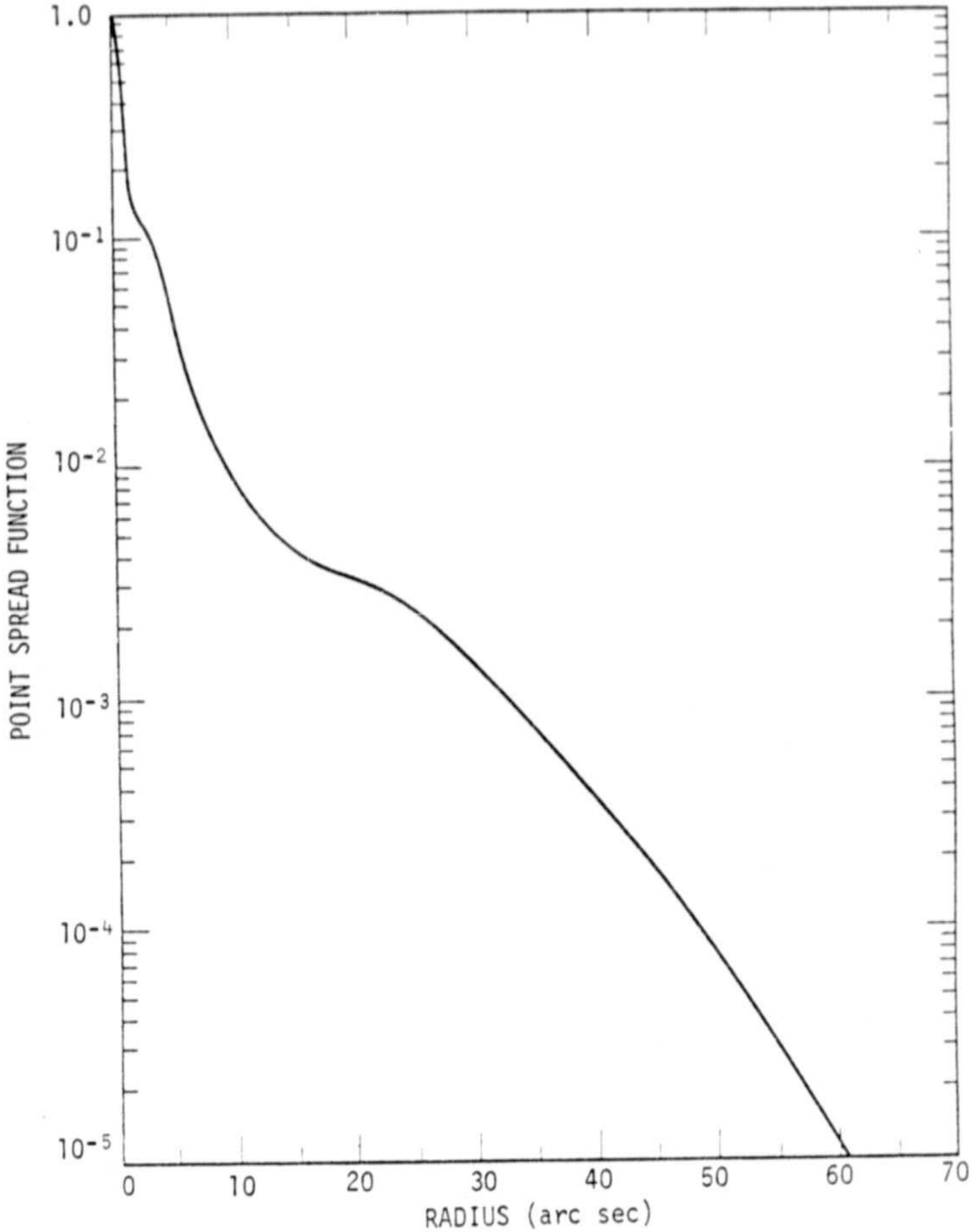


FIGURE 7. S-056 POINT SPREAD FUNCTION

5. THE INTERPRETATION OF BROADBAND FILTER OBSERVATIONS

In the interpretation of broadband X-ray filter observations, we are interested in converting the observed exposure on the film (in photon cm^{-2}) to intensity emitted by the sun. The equation relating the quantities is

$$\phi_n = \frac{A_T t}{f^2} \int \eta_n(\lambda) \frac{I_\lambda(\lambda)}{h\nu} d\lambda \quad ,$$

where

ϕ_n - exposure (photon cm^{-2})

A_T - telescope collecting area (cm^2)

f - telescope focal length (cm)

t - exposure time (sec)

η_n - filter-telescope transmission of filter n

I_λ - specific intensity or radiance (erg sec^{-1} cm^{-2} sr^{-1} $\Delta\lambda^{-1}$)

λ - wavelength (Å or cm)

$h\nu$ - energy of photon (erg) at wavelength λ.

We can then write

$$\int \eta_n(\lambda) \frac{I_\lambda(\lambda)}{h\nu} d\lambda = \frac{f^2}{A_T t} \phi_n$$

which is the specific photon intensity or photon radiance multiplied by the filter-telescope transmission and integrated over wavelength. It has the geometric properties of the telescope removed but still includes the transmission properties. To proceed further, we must assume a spectrum for $I_\lambda(\lambda)$.

To allow easy comparison with other observations, we can assume a simplest reasonable case: I_λ is independent of wavelength. Then

$$\int \eta_n(\lambda) \frac{I_\lambda}{h\nu} \, d\lambda = I_\lambda \int \eta_n(\lambda) \frac{d\lambda}{h\nu}$$

$$= \frac{I_\lambda}{hc} \int \eta_n(\lambda) \lambda \, d\lambda$$

where c is the velocity of light (cm sec^{-1} or Å sec^{-1}).

The integral

$$\int \eta_n(\lambda) \lambda \, d\lambda$$

has been evaluated for the S-056 X-ray filters and is given in Table 14.

TABLE 14. $\int \eta_n(\lambda) \lambda \, d\lambda$ FOR S-056 X-RAY FILTERS

FILTER NUMBER n	$\int \eta_n(\lambda) \lambda \, d\lambda$ (Å^2)
1	2.82
2	11.3
3	5.02
4	9.61
5	1.75

To determine physical parameters such as temperature and emission measure, we do not assume a flat spectrum as above but rather use a theoretical spectrum for a high-temperature, optically thin plasma of solar coronal composition. Because the emission coefficient can be separated into density-dependent (proportional to N_e^2) and temperature-dependent factors, under the assumption of an isothermal line-of-sight, the ratio of intensities through two filters yields the temperature. Using the temperature and the observed intensity, we then obtain the linear emission measure (integral of N_e^2 along the line of sight.

6. 15 JUNE 1973 FLARE AND ACTIVE REGION 131

An example of work based in part on the preceding section is the study of the flare of 15 June 1973 and Active Region NOAA 131 in which it occurred. Papers were presented at meetings of the American Astronomical Society; the abstracts are given here.

- 146th Meeting, August 1975, San Diego, California

  Analysis of Skylab Soft X-Ray Observations of Solar Active Region 131 (McMath 12379). W. Henze, Teledyne Brown Engineering; E. J. Reichmann, A. C. DeLoach, R. B. Hoover, J. P. McGuire, E. Tandberg-Hanssen, R. M. Wilson, NASA/MSFC; and J. B. Smith, Jr. and D. M. Speich, NOAA/SEL* - We present the morphology and development of NOAA active region 131 (McMath 12379) as observed during June 1973 by the Skylab/ATM NASA-Marshall Space Flight Center/The Aerospace Corporation X-Ray Telescope (S-056). During disk passage, the region produced a number of events including a 1B flare (X-ray class M3) on 15 June. We compare the X-ray images with other data including magnetograms. Using filter-ratio techniques on the X-ray filter-heliograms (with the NASA-MSFC Image Data Processing System - IDAPS), we have determined the temperature, emission measure, electron density, and flux of the active region as a function of time.

- 148th Meeting, June 1976, Haverford, Pennsylvania

  Physical Properties and Energy Analysis of the 15 June 1973 Flare Based on Skylab Operations. W. Henze Jr., Teledyne Brown Engineering; K. R. Krall, University of Alabama in Huntsville; E. J. Reichmann, NASA/MSFC; J. B. Smith Jr., NOAA/SEL; and R. M. Wilson, NASA/MSFC - A Class 1B(M3) solar flare on 15 June 1973 was observed by the ATM instruments on Skylab. Photographs and proportional counter data obtained by the MSFC/Aerospace S-056 X-ray experiment have been used to infer temperatures, emission measures, and densities for the flaring plasma and the active region in which

---

*Presently located at NASA/MSFC.

the flare occurred. Peak temperatures in excess of 15×10^6K and densities on the order of 10^{10} cm^{-3} are obtained. The X-ray data, H-alpha filtergrams, magnetograms, and Skylab observations in other spectral regions are compared with theoretical calculations of the conditions in the flaring plasma. The energetics of the flare are analyzed using one-dimensional hydrodynamic code with a varying magnetic-flux tube geometry and with radiation loss and thermal-conductivity dissipation terms.

A journal paper on the flare and active region is being written in conjunction with colleagues at MSFC and the University of Alabama in Huntsville. The introduction to that paper is as follows.

Although much studied in the past, flares continue to pose interesting problems, especially with regard to the source and release of the flare energy. Until recently, the study of the high-temperature component has been hampered by the lack of observations with sufficient spatial and temporal resolution and sufficient duration to cover the development and evolution of the flare. However, the situation changed with the flight in 1973 of Skylab, which contained several instruments capable of observing in the X-ray and EUV spectral regions. In this paper we present results obtained by the Marshall Space Flight Center/Aerospace Corporation S-056 X-Ray Experiment for the flare of 15 June 1973. The observations, consisting of photographs obtained with an X-ray telescope and proportional counter data, show not only the flare but also the evolution of McMath region 12379 (NOAA 131), in which the flare occurred. We also analyze the energy requirements of the flaring plasma.

The primary S-056 instrument was a glancing incidence telescope of Wolter's Type 1 configuration. The two mirrors, made of fused silica, focused the solar image on photographic film. The use of five broadband X-ray filters with different bandpasses, mostly between 6 and 22 Å with one filter having a long wavelength window from 27 to 47 Å, allowed the determination of physical parameters such as temperature and emission measure. During flares, the telescope cycled rapidly through three of the filters. It is this rapid cycling through different filters, combined with the "hard" spectral transmission of the filters, that makes the S-056 instrument so suitable for the study of high-temperature transient events such as flares. The secondary S-056 instrument was the X-Ray Event Analyzer (X-REA), consisting of two proportional counters with different windows. The X-REA, providing data similar to SOLRAD observations, observed the whole Sun, although during a flare the count rate was dominated by the flare emission. Changeable aperture sizes increased the dynamic range, and pulse height analysis yielded coarse spectral information.

The 15 June 1973 flare has also been studied by groups using other Skylab observations. Cheng and Widing have used the Fe XXIII - XXIV emission in the XUV spectra obtained by the Naval Research Laboratory to find a peak temperature of 16×10^6K. The hottest regions are found at the apex of the arch-like structures connecting the lower-temperature ribbons and thus lie over the line where the longitudinal component of the photospheric magnetic field is zero. Pallavicini et al. have examined images obtained by the American Science and Engineering X-ray telescope to study the morphology of the event. They have also used Solrad X-ray data to obtain physical parameters.

In the remainder of this paper we outline the plasma diagnostic techniques used to obtain physical parameters from the data and present the S-056 observation of both the active region and the 15 June 1973 flare. The morphology and evolution of the region and flare are discussed, incorporating other data such as Hα photographs and magnetic field maps. Physical parameters including temperature, emission measure, and density are inferred. Finally, we have theoretically modeled the energy input and its time variation to offer a possible explanation of some of the observed characteristics such as the cooling time and the relative times of peak temperature and density.