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ATLAS OF SKYLAB ATM/S056 CORONAL HOLE OBSERVATIONS

By Robert M. Wilson
Space Sciences Laboratory

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16. ABSTRACT

An atlas of coronal hole observations (Patrol Long and Single Frame Long Filter 3) recorded by the Skylab Apollo Telescope Mount/S056 X-Ray Telescope during the first two manned missions is presented. A total of 279 operations (excluding Super Long frames) were determined. Comparisons are made between coronal hole observations performed in the first manned mission and those in the second manned mission, and between a Super Long Filter 3 image and a typical Single Frame (or Patrol) Long image. Additional studies to enhance the S056 coronal hole observations and perhaps to extend coverage into the last manned mission are suggested. The data presented in this report are still in preliminary form.

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ATLAS OF SKYLAB ATM/S056 CORONAL HOLE OBSERVATIONS

I. INTRODUCTION

Long-term observations of coronal holes, regions of depressed emission bounded by apparently large-scale loop structure, were accomplished by the instruments of the Skylab Apollo Telescope Mount (ATM). Initial findings concerning these features have been reported by Vaiana et al. [1,2], Tousey et al. [3], Harvey et al. [4], Huber et al. [5], Krieger et al. [6], Timothy et al. [7,8], Bohlin et al. [9], Feldman et al. [10], and Nolte et al. [11].

Nolte et al. [12] and Wetherbee and Reeves [13] have compiled "atlases" of coronal hole observations from the ATM/S054 and S055 instruments, respectively. This report presents similar findings based on observations performed by the ATM/S056 instrument.

The ATM/S056 X-Ray Telescope observed the Sun during all manned operational phases of the Skylab. It obtained some 27 000 photographs (filter-heliograms) of the Sun, as well as more than 1100 hours of X-ray proportional counter data. The instrument has been described by Walsh et al. [14] and Underwood et al. [15,16], and its orbital performance has been reported by deLoach et al. [17].

One of the S056 X-ray filters was especially designed to reveal the faint X-ray emanations from the Sun. This soft X-ray filter, designated Filter 3, was an 0.086 mil foil of titanium (bandpass: 6 to 14, 27 to 47 Å, where bandpass is defined as that wavelength region in which the product of filter transmission and telescope reflectivity exceeds 10^{-4}). Operations were performed with this filter (and the other four X-ray filters) in the instrument's Patrol, Single Frame, and Active modes and have yielded some data concerning coronal holes and X-ray bright points. The titanium filter, when used in conjunction with the other X-ray filters, also allows the determination of line-of-sight temperatures and densities following the techniques described by Vaiana et al. [18].

Approximately midway through the second manned mission (i.e., late August 1973), the titanium filter developed a visible light leak. This light leak appeared in the images to varying degrees and, in fact, progressively deteriorated the value of the filter through the last manned mission. In some cases, the light leak appeared as a very faint marking near the edge of the film; in others, it appeared diagonally across the image. Sometimes it would appear in a frame and then disappear for several operations before reappearing. The orientation of the marking and its "degree of blackness" varied, rarely being exactly the same for consecutive Filter 3 operations. The exact cause of this problem is not yet understood.

In addition to the occasional marking on some Filter 3 images, overlapping frames (i.e., a frame superimposed upon the preceding frame's data-block lights because of insufficient film advance) sometimes occurred. The analysis of these frames, however, is a problem only for those X-ray features whose images are found to be in proximity to the data-block light images.

While Filter 3 was the best S056 filter for observing coronal holes, especially when used in conjunction with the Patrol Long (PL), Single Frame Long (SFL), or Super Long (S^L) operational modes, Filter 2 (a 0.250 mil foil of aluminum; bandpass: 6 to 8, 8 to 22 Å) and, possibly, Filter 4 (1.000 mil beryllium; bandpass: 6 to 18 Å), when used in the S^L mode with exposures of several minutes, also sometimes revealed coronal holes. Wilson [19] has compiled a listing of the 552 S^L frames obtained by the S056 instrument and determined their exposure times. Thus, only PL 3 and SFL 3 operations for the first two manned missions (loads 1, 2, and 3) have been included in this report. While all entries may not be frames that specifically show coronal holes, these entries represent all S056 operations (except those found in Reference 19) that were performed to detect their presence. The use of radiography to enhance faint features contained in these data may prove useful in the study of coronal holes, as perhaps will the use of image data processing systems, such as the MSFC IDAPS [20,21].

II. S056 CORONAL HOLE IMAGERY

An example of a typical S056 coronal hole photograph observed in the first manned mission through Filter 3 is shown in Figure 1. The coronal hole appears as the elongated area near central meridian which has no X-ray emission. It extends from the north pole (polar coronal hole also noted) to approximately 20°S and is approximately 15° wide at the equator. Following Timothy et al. [8], this hole is known as coronal hole 1 (CH1).

Coronal holes are much more discernible in the observations of the first manned mission (load 1) than in those of the second manned mission (loads 2 and 3), apparently because of conditions on the Sun during these periods. Figure 2 shows the soft X-ray Sun on August 16, 1973 (second mission), and little evidence of an X-ray Sun, except for an active region or two, is observed. Improved viewing of this same August 16 Sun is observed in Figure 3, which shows an S^L 3. CH1 is noted near the east limb and CH2 is noted near central meridian. The polar coronal hole can also be discerned.

Additional studies concerning the PL, SFL, and S^L Filter 3 images of the first two manned missions are presently underway. Also, an attempt to recover coronal hole photographic data for the last manned mission from the S^L 2 and/or 4 exposures is being considered. Of particular interest is the period from November 27 to December 26, 1973, during which the S054 instrument experienced operational anomalies [12].

III. APPROACH

All PL and SFL Filter 3 operations, as recorded in the "S056 Operations Log," for the first two manned missions were compiled. A total of 279 operations were determined. A review of a third generation Houston-produced (NASA-Johnson Spacecraft Center Photolab) film was then made to reveal those frames whose images were full disk and those that were partial disk. Finally, the results of this study were recorded in Tables 1 through 3 in this report.

IV. TABULAR INFORMATION

Table 1 lists the PL 3 observations obtained during the first manned mission (SL 2 load 1). No SFL 3 operations were performed. Tables 2 and 3 identify the PL 3/SFL 3 observations performed during the second manned mission (SL 3 loads 2 and 3, respectively). For the S^L 3 observations, see Reference 19.

In Tables 1 through 3 "Date" identifies the date of the operation, "F.N." identifies the frame numbers of the observation as identified in the S056 Operations Log, "DOY" is the day-of-year of the observation, "UT" is the universal time of the start of the exposure, "FD/PD" denotes whether the frame is full disk or partial disk, and "Comments" are the remarks relative to the specific frames. The following is an explanation of the abbreviated annotations written in the "Comments" column of Tables 1 through 3:

OLI:	Overlapping image
SFL 3:	Single Frame Long, Filter 3
VLL:	Visible light leak
VLL (VF):	Visible light leak, very faint
VLL (VD):	Visible light leak, very dark
*:	Very darkened image frame

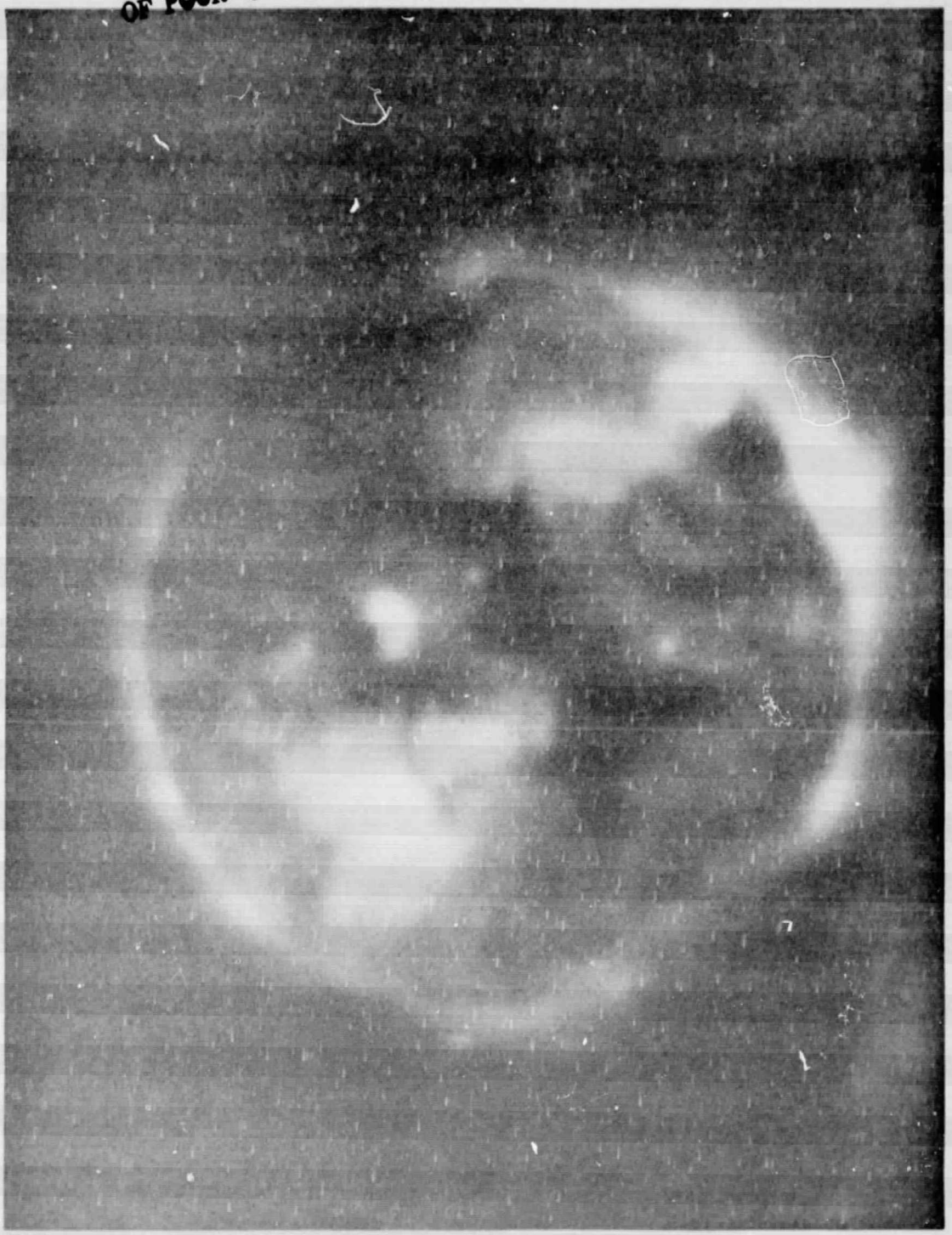

Figure 1. Photograph of a typical S056 coronal hole observation (SL 2 load 1); Patrol Long Filter 3 (6 to 14, 27 to 47 Å), June 1, 1973 (DOY 152), 0212:23½ UT, exposure 2:39, CH1 observed near central meridian, north is to upper left, east is to lower left. (The "fishhooks" noticeable in the photograph are pressure marks which randomly occurred on all film loads (see Reference 17).)

Figure 2. Photograph of a typical S056 coronal hole observation (SL 3 load 2); Single Frame Long Filter 3 (6 to 14, 27 to 47 Å), August 16, 1973 (DOY 228), 1459:03½ UT, exposure 2:38¼, north is to upper right, east is to upper left.

Figure 3. Photograph of a typical S056 coronal hole observation (SL 3 load 2); Super Long Filter 3 (6 to 14, 27 to 47 Å), August 16, 1973 (DOY 228), 1519:33¼ UT, exposure 10:00¼, CH2 observed near central meridian, CH1 on east limb, north is to upper right, east is to upper left.

TABLE 1. PL 3 OBSERVATIONS (SL 2 LOAD 1)

Date	F.N.	DOY	UT	FD/PD	Comments
5/29/73	51	149	1945:03½	FD	
5/30	69	150	0013:10½	FD	
	102		0155:09¼	FD	
	141		1432:46	FD	
	238		1716:45¾	FD	
5/31	376	151	0111:24¾	FD	
	415		1342:42½	FD	
	439		1646:52	PD	
	457		1709:39¼	PD	
	475		1814:51½	PD	
	493		1839:28¾	PD	
	568		2113:14¼	PD	
6/1	672	152	0212:23½	FD	
6/2	690	153	1359:28¼	FD	
6/3	924	154	0049:10½	PD	
	930		0108:56½	PD	
	942		0214:16	FD	
	960		1452:55	FD	
	972		1607:33	FD	
	1023		1801:36¾	PD	
	1056		2100:37¾	PD	
6/4	1133	155	0134:14½	FD	
	1172		1539:31½	FD	
	1205		1838:16	FD	
	1211		1905:21	FD	

TABLE 1. (Continued)

Date	F.N.	DOY	UT	FD/PD	Comments
6/5/73	1313	156	0052:50¾	PD	
	1337		0222:09¾	FD	
	1355		1503:09	FD	
	1433		2106:16	PD	
	1451		2128:36¾	PD	
	1470		2235:37¾	PD	
	1488		2258:27¾	PD	
6/6	1500	157	0142:28¾	FD	
	1518		1425:14½	FD	
	1530		2013:13¾	PD	
6/7	1563	158	0058:43½	FD	
6/8	1581	159	0207:45½	FD	
	1616		1614:04¼	FD	
6/9	1634	160	0133:15½	FD	
	1646		1348:55	FD	
6/10	1731	161	0022:37	PD	
	1759		0201:10¼	FD	
	1817		1616:29¾	FD	
	1873		1905:09¼	PD	
	1879		1921:44¾	PD	
6/11	1995	162	0124:00¾	FD	
	2034		1357:26½	FD	
	2092		1958:23¼	PD	
	2110		2020:59½	PD	
6/12	2270	163	0209:51	FD	

TABLE 1. (Concluded)

Date	F.N.	DOY	UT	FD/PD	Comments
6/12/73	2288	163	1450:16¾	FD	
	2300		1607:37	PD	
	2384		1922:48¼	PD	
	2390		1938:13¼	PD	
6/13	2521	164	0134:06	FD	
	2538		1551 25¾	FD	
	2584		1844:55½	PD	
	2602		2008:39¼	PD	
	2620		2031:08¼	PD	
	2638		2140:22	PD	
	2656		2203:23¾	PD	OLI
6/14	2733	165	0112:31	FD	
	2745		1340:33¾	FD	
	2791		1819:50¾	FD	
6/15	2937	166	0005:20½	FD	
	2955		1110:54	FD	
	2967		1224:19½	~FD	
	3010		1358:18½	PD	
	3352		2201:35¼	FD	
6/16	3370	167	1032:10	FD	
	3424		2109:38½	FD	
6/17	3463	168	0941:48½	FD	
6/18	3769	169	1036:01¾	FD	
	3972		2121:20¼	FD	
	3976		2133:11	FD	

TABLE 2. PL 3 AND SFL 3 OBSERVATIONS (SL 3 LOAD 2)

Date	F.N.	DOY	UT	FD/PD	Comments
8/8/73	304	220	0102:36	~FD	SFL 3
	320		1501:38 1/4	FD	
8/9	476	221	0146:59 3/4	PD	
	512		1547:55 3/4	FD	
	711		1845:21 1/4	FD	
	858		2146:38 3/4	FD	
8/10	936	222	1432:12 3/4	FD	
8/11	1034	223	0133:04	FD	
	1082		1401:08	FD	
	1188		1841:30	PD	
	1206		1905:01 3/4	PD	
	1224		2010:35 1/4	PD	
	1242		2032:58 1/4	PD	
	1260		2146:00 3/4	PD	
	1278		2209:22 1/4	PD	
8/12	1290	224	0049:20	FD	
	1332		1804:29	FD	
8/13	1492	225	0142:56 1/4	FD	
	1534		1431:03	FD	
	1709		2048:11 1/4	FD	
8/14	1866	226	0105:26 3/4	FD	
	1885		1332:34	FD	
	1921		1500:26 1/4	PD	
	1939		1524:28	PD	
	1957		1632:23	PD	

TABLE 2. (Continued)

Date	F.N.	DOY	UT	FD/PD	Comments
8/14/73	1975	226	1706:42 1/4	PD	
	1991		1817:49 1/4	PD	
	2182		2247:01 3/4	PD	
8/15	2251	227	0021:27 1/2	PD	
	2308		0155:49 1/2	PD	
	2374		1320:58	PD	SFL 3
	2383		1436:32 1/4	FD	
	2800		2332:23	PD	
8/16	2848	228	0119:19 1/2	FD	
	2872		1220:52 1/2	PD	
	2890		1346:23 1/2	FD	
	2918		1459:03 1/2	FD	SFL 3
	3003		2004:36 3/4	PD	
	3009		2024:04 1/2	PD	
	3025		2130:17 3/4	PD	
	3043		2156:49 3/4	PD	
	3057		2256:18	PD	
	3075		2331:39 3/4	PD	
8/17	3093	229	0033:12 3/4	PD	
	3111		0057:49	PD	
	3124		0205:15 1/4	FD	
	3136		0227:54 1/4	PD	
	3166		1146:50 1/2	FD	
	3310		1619:24 3/4	PD	
	3415		1913:44 1/4	PD	

TABLE 2. (Continued)

Date	F.N.	DOY	UT	FD/PD	Comments
8/17/73	3433	229	1936:03¼	PD	
	3451		2058:16¾	PD	
8/18	3470	230	0014:05	PD	
	3488		0124:41½	FD	
	3550		1354:56½	FD	
	3586		1529:25¼	FD	
	3628		1700:33¼	PD	
	3803		2201:09	PD	
	3821		2317:14½	PD	
8/19	3839	231	0042:05¾	PD	
	3881		1142:32½	FD	
	3905		1323:45	FD	
	4039		1921:03½	FD	SFL 3
	4043		1942:59½	PD	
8/20	4214	232	0021:42	FD	
	4238		0135:23½	FD	
	4326		1240:04¾	FD	
	4428		1543:26½	FD	
	4531		1847:16	FD	
8/21	4714	233	0058:39¼	FD	
	4739		0232:48¾	FD	
	4825		1323:36	FD	
	4909		1632:29¾	PD	
	5018		1923:29¾	PD	SFL 3
	5021		1934:49	PD	SFL 3

TABLE 2. (Concluded)

Date	F.N.	DOY	UT	FD/PD	Comments
8/21/73	5022	233	1939:12¾	PD	SFL 3
	5027		2003:07¾	PD	SFL 3
	5028		2008:19	PD	SFL 3
	5043		2123:43¾	PD	SFL 3; VLL(VF)
	5045		2130:29½	PD	SFL 3
	5047		2137:12½	PD	SFL 3
	5049		2142:29¼	PD	SFL 3
	5053		2235:14½	FD	VLL(VF)
	5059		2253:30	FD	VLL(VF)
8/22	5078	234	0007:49	FD	
	5084		0025:13½	FD	
	5097		0151:06¾	FD	
	5139		1306:00¾	FD	
	5241		1736:18	FD	
	5277		1918:57¼	PD	VLL(VF)
	5407		2328:28½	FD	
	5413		2346:26	FD	VLL(VF)
8/23	5426	235	0109:56¼	FD	
	5458		1218:17¾	~FD	
	5464		1233:58	~FD	VLL(VF)
	5476		1344:07	FD	VLL(VF)
8/24	5645	236	0040:40	FD	VLL(VF)

TABLE 3. PL 3 AND SFL 3 OBSERVATIONS (SL 3 LOAD 3)

Date	F.N.	DOY	UT	FD/PD	Comments
8/24/73	3	236	2344:11¾	~FD	VLL(VF)
8/25	120	237	0145:38¼	FD	
	138		1238:21¼	FD	
	337		1844:14	FD	VLL(VF)
8/26	600	238	0053:10	FD	VLL(VF)
	636		1327:25	FD	VLL(VF)
8/27	949	239	0009:42½	FD	VLL
	985		1241:35¾	FD	VLL(VF)
	1089		1700:17½	PD	VLL(VF)
	1206		2020:54	PD	VLL(VD)
	1218		2048:57¼	PD	VLL(VD)
	1235		2153:08¾	PD	VLL(VF)
	1253		2215:35¾	PD	
	1271		2324:28¼	PD	
8/28	1316	240	0058:41¼	FD	VLL(VD)
	1406		1140:34½	PD	VLL(VF)
	1449		1224:26½	PD	SFL 3; VLL(VD);
	1476		1331:36¾	FD	VLL(VD)
	1613		1651:53¾	PD	SFL 3
	1666		1936:57¾	PD	VLL(VD)
	1669		2000:20	PD	VLL(VD)
8/29	1938	241	0147:09¼	FD	VLL(VD)
	1977		1240:20¾	FD	VLL(VD)
	2001		1425:33½	PD	
	2054		2033:21¼	PD	VLL(VF)

TABLE 3. (Continued)

Date	F.N.	DOY	UT	FD/PD	Comments
8/29/73	2074	241	2055:42½	PD	VLL(VF)
	2135		2346:25	PD	VLL(VD)
8/30	2153	242	0243:36	FD	VLL(VD)
	2192		1210:59	PD	SFL 3; VLL(VF)
	2194		1217:23¾	PD	SFL 3; VLL(VF)
	2196		1224:52	PD	SFL 3; VLL(VF)
	2198		1231:07¾	PD	SFL 3; VLL(VF)
	2207		1338:21½	FD	VLL(VD)
	2249		1458:53½	PD	VLL(VD)
	2255		1516:28¾	PD	VLL(VD)
	2417		2303:20	PD	VLL(VD)
8/31	2435	243	0027:24½	FD	VLL(VD)
	2491		1312:01¾	FD	VLL(VD)
	2515		1435:06¾	PD	VLL(VF)
	2527		1550:05¾	PD	VLL(VF)
	2533		1607:25	PD	VLL(VF)
	2551		1723:51¼	PD	VLL(VF)
	2557		1751:57½	PD	VLL(VF)
	2599		1930:09½	PD	
9/1	2762	244	0114:55	FD	VLL(VD)
	2772		0125:58	FD	SFL 3; VLL(VD)
	2782		1219:10½	FD	VLL(VD)
	2812		1335:51¾	PD	VLL(VF)
	2875		1658:56½	PD	VLL(VF)
9/2	3008	245	0036:36¾	FD	VLL(VD)

TABLE 3. (Continued)

Date	F.N.	DOY	UT	FD/PD	Comments
9/2/73	3123	245	1318:20	FD	VLL(VD)
	3229		2036:30¼	PD	SFL 3; VLL(VF)
	3233		2058:51	PD	SFL 3; VLL(VD)
	3240		2114:55¼	PD	SFL 3; exposure :04¾; VLL(VD); OLI
9/3	3268	246	0124:29	FD	VLL(VD)
	3290		1223:18¼	FD	VLL(VD)
	3327		1817:55¼	PD	SFL 3; VLL(VD)
	3329		1855:17	PD	SFL 3; VLL(VD)
9/4	3369	247	0047:20¾	FD	VLL(VD)
	3385		0212:52¼	FD	SFL 3; VLL(VD)
	3392		0228:55	FD	SFL 3; VLL(VD)
	3422		1318:23	FD	VLL(VD)
	3479		1948:24	FD	VLL(VD)
	3533		2234:59¾	PD	VLL(VD)
9/5	3545	248	0007:36¾	PD	VLL(VD)
	3569		0137:48¼	FD	VLL(VD)
	3586		1241:59	FD	VLL(VD)
9/6	3850	249	0101:06¼	FD	VLL(VD)
	3887		1318:19½	FD	VLL(VD)
	3995		2308:51¼	FD	SFL 3; VLL(VD); *
9/7	4014	250	0146:44	FD	VLL(VD); *
	4197		1441:48	FD	SFL 3; exposure :30; VLL(VD)
9/8	4320	251	0104:10¾	FD	VLL(VD); *
	4369		1331:06¾	FD	VLL(VD); *
	4424		1809:51½	FD	SFL 3; VLL(VD); OLI; *

TABLE 3. (Continued)

Date	F.N.	DOY	UT	FD/PD	Comments
9/8/73	4439	251	1931:29 3/4	FD	SFL 3; VLL(VD); *
9/9	4486	252	0158:14	FD	VLL(VD); OLI; *
	4511		1248:52 1/2	FD	VLL(VD); *
9/10	4892	253	0422:13 3/4	FD	VLL(VD); *
	4925		1205:52 3/4	FD	VLL(VD); *
	5027		1649:26	PD	VLL(VD)
9/11	5079	254	0202:32	FD	VLL(VD); *
	5090		1131:04 3/4	FD	VLL(VD); *
	5102		1153:50	?	SFL 3; VLL(VD); OLI; *
	5112		1501:38	?	SFL 3; VLL(VD); OLI; *
9/12	5215	255	0122:21 3/4	FD	VLL(VD); *
	5235		1351:07	FD	VLL(VD); OLI; *
	5291		2133:28 1/2	?	SFL 3; VLL(VD); *
9/13	5326	256	0213:46	FD	VLL(VD); OLI; *
	5343		1148:11 3/4	FD	VLL(VD); OLI; *
9/14	5424	257	0129:50 1/4	FD	VLL(VD); OLI; *
	5448		1238:42 1/2	FD	VLL(VD); OLI; *
	5500		1553:17	PD	SFL 3; VLL(VD); *
9/16	5547	259	0152:44 3/4	FD	VLL(VD); OLI; *
	5564		1237:54 1/4	FD	VLL(VD); OLI; *
	5583		2334:04	FD	VLL(VD); OLI; *
9/17	5595	260	1025:49 1/4	FD	VLL(VD); OLI; *
	5618		2134:24 1/4	?	SFL 3; VLL(VD); OLI; *
9/18	5635	261	0947:26 3/4	FD	VLL(VD); *
	5657		2219:31	FD	VLL(VD); OLI; *

TABLE 3. (Concluded)

Date	F.N.	DOY	UT	FD/PD	Comments
9/19/73	5674	262	0900:28	FD	VLL(VD); OLI; *
	5699		2127:01¼	FD	VLL(VD); OLI; *
9/20	5719	263	1013:15¾	FD	VLL(VD); OLI; *
	5745		2222:38¾	FD	VLL(VD); OLI; *
9/21	5761	264	0749:11	FD	VLL(VD); *
	5771		0805:33¼	?	SFL 3; VLL(VD); OLI; *
	5795		1834:39	FD	VLL(VD); OLI; *

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APPROVAL

ATLAS OF SKYLAB ATM/S056 CORONAL HOLE OBSERVATIONS

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 beer reviewed and approved for technical accuracy.

Anthony C. deLoach

ANTHONY C. deLOACH
Chief, Solar Sciences Branch

William C. Snoddy

WILLIAM C. SNODDY
Chief, Astronomy and Solid State Physics Division

Charles A. Lundquist

CHARLES A. LUNDQUIST
Director, Space Sciences Laboratory

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