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Apollo Telescope Mount Experiments Technology

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APOLLO TELESCOPE MOUNT EXPERIMENTS TECHNOLOGY

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ABSTRACT

The Skylab Apollo Telescope Mount (ATM) experiments, consisting of a white light coronagraph, four ultraviolet instruments, two X-ray telescopes and two Hydrogen-alpha telescopes, observed the Sun daily for nine solar rotations. The results have only begun to be evaluated, but it is already apparent that many theories of solar physics will undergo significant revisions as results are further developed. The ATM instruments were individually larger, more complex, and provided better spatial resolution than previous solar satellite instruments. An additional major advantage of the telescope complex was its ability to simultaneously collect multispectral data of specific solar phenomena. To maximize the scientific benefits of the orbiting observatory, a coordinated observing program involving worldwide ground-based observatories was conducted. A description of the Skylab, the ATM and the ATM experiments will be given. The daily process of flight planning and execution will be described. Examples of scientific data and some preliminary findings will be presented.

INTRODUCTION

The Skylab Apollo Telescope Mount (ATM) scientific instruments recently completed daily observations of the Sun for nine solar rotations involving a total of 2203 hours. The line of sight from orbit was a minimum of 400 kilometers above the Earth. These observations have provided scientists with the most complete set of continuous solar data ever accumulated and have been compared to Galileo's first look through his telescope centuries ago. Spectral coverage of the instrument complex ranged from soft X-rays to the visible wavelengths. The spatial resolution of each instrument was an order of magnitude better than any similar instrument flown on previous satellites. A major advantage of the ATM was the availability of astronaut observers because they could point the instruments precisely at very small targets, and immediately react to unpredictable transient events. These capabilities were beyond the competence of unmanned satellites.

In addition to solar observations, the design of the ATM instruments offered unique capability for collecting high quality data on the Mercurian atmosphere, Earth-Moon Lagrangian points, the Earth's atmosphere and, during the final Skylab flight, on Comet Kohoutek.

To complement the data acquired by the orbiting ATM, hundreds of scientists around the world conducted simultaneous observations from their respective ground based observatories.

Now that the Skylab mission has been completed and a wealth of data has been returned to Earth and the waiting scientists, extensive data analysis programs have been started. The massive scientific yield will take years to evaluate but it is already apparent, from quick-look data, that many theories of solar energy and mass transfer must be revised.

Limited space precludes a complete discussion of all ATM experiments. Many technical papers could be and surely will be written on each of the following sections. The contents of this paper, therefore, will consist of a brief description of: (1) the Skylab space station, the ATM module, and the ATM scientific instruments; (2) techniques used by flight and ground teams to collect the data; (3) samples of the solar data and; (4) some preliminary scientific findings.

HARDWARE DESCRIPTION/PERFORMANCE

Skylab Description

The Skylab Space Station was launched on May 14, 1973, from Cape Kennedy, Florida. As shown in Figure 1, the launch configuration consisted of the Saturn V launch vehicle, which included the S-IC first stage, the S-II second stage and interstage structure, and the payload, which included the space station, instrument unit and the payload shroud. The orbiting configuration, shown in Figure 2, consisted of the Command and Service Module (CSM), which was used to ferry the crew; the Multiple Docking Adapter (MDA), which provided docking capability for the CSM, also housed the ATM control panel and provided storage space; the Airlock Module (AM) through which the crew egressed for extra-vehicular activities; the Orbiting Workshop (OWS), which provided space for storage, experiment activities and crew quarters; and the ATM module, which included the solar.
The ATM experiment instruments consisted of the following:

1. White Light Coronagraph (S052); built by Ball Brothers Research Corporation of Boulder, Colorado, under contract to the High Altitude Observatory (HAO), also of Boulder. Dr. R. MacQueen of HAO is the principal investigator.

2. X-Ray Spectrographic Telescope (S054); built by American Science and Engineering Corporation (AS&E) of Cambridge, Massachusetts. Dr. G. S. Vaiana of AS&E is the principal investigator.

3. UV Scanning Polychromator Spectroheliometer (S055); built by Ball Brothers Research Corporation under contract to Harvard College Observatory, Cambridge, Massachusetts. Dr. E. Reeves of the Observatory is the principal investigator.

4. XUV Spectrograph/Spectroheliograph (S082); built by Ball Brothers Research Corporation under contract to the Naval Research Laboratory (NRL), Washington, D. C. Dr. R. Tousey of NRL is the principal investigator.

5. X-Ray Telescope (S056); built by Marshall Space Flight Center (MSFC), Huntsville, Alabama. Mr. J. Milligan of MSFC is the principal investigator.

6. Two H-Alpha Telescopes; these telescopes were the primary means for boresight pointing for the ATM experiment instruments. The H-Alpha No. 1 instrument was actually a part of the S055 Experiment. The instruments were built by Perkin-Elmer of Norwalk, Connecticut.

All ATM experiments were managed and integrated into the Skylab Program by the National Aeronautics and Space Administration's Marshall Space Flight Center at Huntsville, Alabama.

The optical layout of the S052 coronagraph is shown in Figure 7. Light enters the aperture and passes over a series of three external occulting disks which block out the very bright light from the solar disk and most of the associated diffracted light. The effective radius of each disk is approximately one and one-half times the radius of the Sun. The remaining coronal image is then transmitted through the primary objective lens at the entrance to the optics housing and then over an additional occulting disk which is movable in pitch and yaw. Using fine sun sensors, the
internal occulting disk is automatically moved to eliminate the final traces of unwanted scattered light. The image is then transmitted through and past a field lens, the Lyot spot, and a secondary objective lens to the first fixed folding mirror, then travels along the rear wall of the optics housing to a second fixed folding mirror. From there the image passes through a polaroid wheel to the replaceable film camera. The polaroid wheel has one clear opening and three other openings filled with polaroids (60-degree E vectors). The polaroid position sequence is controlled by the camera programmer and varies with the particular operating mode selected by the ground or flight crews.

A movable mirror is located between the two fixed folding mirrors to direct the beam to another fixed folding mirror and on to a low light level television camera located on the top of the optics housing. The TV image was primarily provided as an aid to the astronauts in pointing the instruments and routine coronal observations. This feature was essential to the accurate and rapid collection of data during fast-moving coronal transient events. The image was also transmitted to the ground each morning for use by the ATM planning group.

A design feature that also proved valuable was the automatic logic which automatically closed the ATM S052 aperture door if the angle between the optical axis of the coronagraph and the Sun line exceeded five arc-minutes. This precaution was necessary since estimates showed the resulting scattered light would cause permanent damage to the polaroids and the film camera shutter. The sensor for this feedback logic was located at the primary objective lens. A finer control was also incorporated to prevent camera operation if the above angle exceeded 20 arc-seconds, since scattered light in that condition would mask out the very faint coronal features which were the prime experiment targets. The sensor for this logic was located at the internal occulting disk.

The S054 X-ray spectrographic telescope is depicted in Figure 8. Light from the Sun first strikes a thin aluminum prefilter covering the aperture of the instrument. Light then proceeds into a set of confocal and concentric grazing-incidence mirrors. Inside the main mirror is a small grazing-incidence X-ray mirror located on the optical axis that provides an image to the image dissector unit (IDT). The IDT converts the image to white light and displays the results on a cathode ray tube located on the ATM C&D panel. The images from the main mirrors proceed either through or past the X-ray diffraction grating which has a capability for mechanically moving in and out of the image path. This feature provides a capability of converting the telescope from an imaging device to a spectrographic device. The primary mode used in flight was with grating "out". The grating "in" position was used primarily for recording flare data. From the grating, the image proceeds through one of six apertures in the filter wheel assembly. One aperture is clear and the other five are filled with various filters which divide the 2 - 60 Å spectral range into approximately five spectral bands. The image is then transported to the photographic camera for recording. In addition, a visible light path is allowed through the telescope and is recorded on the film for calibration purposes.

In addition to the telescope, a scintillation detector is coupled to a photomultiplier which produces X-ray flux readings. These readings were both transmitted to the ground as scientific data and displayed to the crew. The output of the photomultiplier is also used to drive a flare alarm system which provides an audible alarm when the X-ray flux reaches a threshold setting established by the crew. In-flight experience revealed that the photomultiplier was insufficiently shielded from background radiation, and consequently, the minimum threshold setting was necessarily higher than previously planned. In-flight problems with the filter wheel assembly will be discussed later.

The layout of the S055 instrument is shown in Figure 9. Solar rays pass through the entrance aperture to an off-axis parabolic primary mirror. From there, the rays pass through the spectrometer entrance slit which is five arc-seconds by five arc-seconds, and then on to a grating which disperses the spectra to seven photomultipliers and a zero order detector located on the Rowland circle focal plane. The primary mirror is capable of moving in both pitch and yaw and creates a 60-line by 60-step raster pattern. The width of the raster is five arc-minutes by five arc-minutes in the full raster mode. The grating is capable of moving through an arc of six degrees to provide complete scanning of the entire 300 to 1300 Å spectral range. The possible operating modes are:

1. Mirror raster mode, during which the grating is fixed at a given position and the mirror is fully rastered providing a five arc-minute by five arc-minute simultaneous recording of the emissions of seven distinct wavelengths. The selection of the seven lines is determined by the grating position.

2. Mirror line scan, during which the grating is again fixed and a single selected raster line is continuously swept to record a five arc-second by five arc-minute simultaneous recording of the emissions of seven distinct wavelengths.

3. Grating scan, during which the mirror is fixed at a selected position within the raster pattern and the grating is moved to provide an emission spectra for the complete 1000 Å spectral range.

The zero-order detector was used in flight to determine the coalignement of the S055 slit with the S082B slit and the mechanical reticle in the H-alpha telescopes.

In-flight operation of this instrument was trouble free except for repeated cutoffs of detector #5. A very sensitive current-sensing
override circuit was provided in the detector control logic to prevent the runaway of the high voltage power supply during high flux events that could damage adjacent hardware. The threshold level of the override circuit for detector #5 apparently had been set at a marginal level and repeatedly tripped. The override circuits for the other detectors worked satisfactorily but did on occasion trip the respective detectors during high flux events.

The S056 optical arrangement as shown in Figure 10 is similar to the S054 instrument in that it uses parabolic/hyperbolic grazing-incidence optics and a filter wheel to produce whole disk images of the Sun in the required X-ray spectral range. The major differences between the two X-ray instruments are (1) the S056 instrument is an imaging device only and has no spectrographic ability, (2) the collecting area of the S056 is less than the S054 instrument since, in the latter case, nesting confocal mirrors are used instead of one main mirror as in the S056 case, (3) the S054 instrument uses Kammenga-coated mirrors, as compared to the S056 uncoated quartz mirrors, and (4) the filters for the S056 instrument were selected to concentrate on the harder X-ray emissions. With respect to flux measurements, the S056 instrument uses gas-filled proportional counters instead of photomultipliers. The proportional counters are not as sensitive to background radiation in orbit and, consequently, provide flux resolution at low levels.

The major difficulty experienced with this instrument was confined to the photographic cameras which experienced intermittent stoppages. In all instances the malfunction was corrected by a new start command by the crew.

The S082A diagram in Figure 11 shows the Sun's rays entering through the instrument aperture and reflecting off a concave grating ruled with 3600 lines per millimeter. From there, the resulting spectral images are transmitted through a thin aluminum filter onto an off-axis parabolic mirror, through another thin aluminum filter to the face of a low light level vidicon with a conversion layer on its face as shown in Figure 13. The resulting image shows an integrated whole disk image of the Sun between the wavelengths 150 to 650 Å. This image is displayed on the TV monitor on the ATM C&D panel and was used by the crew for general observations and location of certain UV features. It was also transmitted to the ground each morning for use in the daily NOAA solar forecast.

Due to the similarity of the two telescopes, only the optical path of the H-alpha No. 1 telescope will be discussed here.

Light from the Sun first strikes the heat rejection window which covers the aperture of the instrument. In the spectrograph the light path enters the instrument aperture and proceeds to a movable off-axis parabolic mirror from which it reflects through the spectrographic entrance slit to a predisperser grating as shown in Figure 12. The entrance slit is 2 x 60 arc-seconds. The predisperser grating has two positions, one for the first order spectra and the other for the second order spectra. The predisperser grating is ruled in several bands of 150 and 300 lines per millimeter to offset the vertical astigmatism from the long entrance slit. From the predisperser grating the image proceeds through an exit slot (wave band aperture) to the main grating which contains 500 lines per millimeter. The resulting spectra is then recorded on a film strip located at the Rowland circle focal plane. A three arc-minute image of the forward face of the entrance slit plate is picked off by a pointing reference image dissector tube. This image, which shows the slit superimposed on a three arc-minute white light image of the Sun, was displayed to the astronaut on the TV monitors located on the ATM C&D panel. In addition, an output of the image disk tube is processed through a closed loop feedback system which rotates the primary mirror so that the slit position can be maintained on the limb of the Sun or a pre-programmed offset from the limb of the Sun. This image compensation system has the capability of maintaining a pre-determined slit position with respect to the limb of the Sun within 1 arc-second.

A manual override of the feedback system was provided to the crew for crew pointing and was utilized during the last several days of the SL-4 flight when the output from the image dissector tube degraded to such an extent that the feedback system became unstable. The TV output from the pointing reference systems was used for in-flight co-alignment of this slit with the S055 slit and the mechanical reticles in the H-alpha telescopes.

Hardmounted to the S082B spectrographic instrument is the XUV disk monitor, a less complex instrument providing another optical path from an adjacent aperture through a thin aluminum filter onto an off-axis parabolic mirror, through another thin aluminum filter to the face of a low light level vidicon with a conversion layer on its face as shown in Figure 13. The resulting image shows an integrated whole disk image of the Sun between the wavelengths 150 to 650 Å. This image is displayed on the TV monitor on the ATM C&D panel and was used by the crew for general observations and location of certain UV features. It was also transmitted to the ground each morning for use in the daily NOAA solar forecast.

Due to the similarity of the two telescopes, only the optical path of the H-alpha No. 1 telescope will be discussed here.
The focal plane of the telescope is located behind the telecentric correctors and the mechanical movable reticles are located at this position. The beam progresses into the Fabry-Perot filter system that includes an 8 Å blocking filter and an 0.7 Å Fabry-Perot filter. Both filters are thermally controlled by the same filter oven. From there the beam proceeds to the beam splitter and the two resulting beams are fed, in one case, through additional field lenses to the photographic camera and, in the second case, through a 5X zoom lens to the vidicon television camera. Due to its wider field of view (35 arc-minutes), the H-α 2 telescope was primarily used by the crew for total disk observations. The H-α 1 telescope was primarily used for precise pointing due to its smaller available field of view (4 arc-minutes) and higher spatial resolution on the TV monitor.

Considering the complexity of the instruments, the overall performance was excellent. The major problems encountered were confined to the photographic subassemblies. Out of the 30 replaceable cameras and magazines flown, two jammed and six displayed intermittent film transport problems. In all cases the failed or troublesome subassembly was replaced by the crew during a subsequently scheduled EVA and relatively small amounts of observing time were lost.

Two other problems are worth noting here since the resolution of these problems also demonstrated the benefit of having an in-flight crew.

Early in the first Skylab flight, a piece of cloth thread found its way onto the front external occulting disk of the S052 coronagraph, which resulted in a large degree of localized scattered light. The resulting effect is shown in Figure 16. During the mid-mission EVA on the first flight Commander Conrad reached through the instrument aperture and removed the contaminant with a brush. This feat was particularly remarkable since the cleaning of any optical surface is always a delicate operation even in a laboratory. The coronagraph performance was completely restored.

During the latter part of the final Skylab manned flight the filter wheel inside the S054 X-ray telescope failed to move, sticking between two filter positions. All efforts to solve the problem via remote commands from ground controllers failed. During a subsequent EVA, Commander Carr removed the S054 photographic magazine and used a screwdriver to move the wheel to a preselected filter position, restoring the instrument to nominal operation for that filter position. This accomplishment was also remarkable in that Commander Carr, limited in mobility by his "hard" EVA suit, was able to insert the screwdriver through a small camera aperture, past the shutter blades and pry the wheel to the desired position.

It should be noted that the flight crew's involvement was not limited to removing and installing cameras and repairing failed components. Those contributions were important, but of no less importance was the continual excellent performance by the astronauts as solar observers. This was particularly demonstrated in the acquisition of literally hundreds of recordings of transient solar events. Most of these events, which were not predictable, could not have been collected by unmanned observatories. Nor could unmanned observatories have so precisely pointed the small field-of-view instruments to the proper point in the structure of comparatively small targets.

**FLIGHT PLANNING AND EXECUTION**

An important concept for future missions was developed and proven by the ATM experimenters with respect to solar observing programs. In the beginning, the five ATM principal investigators proposed individual scientific programs, each with several distinct objectives. Efforts to integrate these individual observing programs into practical flight procedures revealed a large number of overlapping objectives. The total required crew time, even after considering overlapping objectives, exceeded the amount of crew time available and, additionally, astronaut training was already extremely complicated. A simplified and more efficient approach was obviously required.

A small group of ATM science representatives and NASA flight planners was formed to solve the problem. Consistent with the traditional scientific method, the group first defined the solar physics problems that it wished to investigate. Considering the available current theories of mass and energy transfer for each problem, the group then formulated a collective plan for acquiring the required data and identified each instrument's possible contribution to the process. The required data-collection sequences were determined and subsequently adjusted where proved necessary during many crew practice sessions, or simulations, on the ground.

The end product of the ATM working group was a list of Joint Observing Programs (JOPs) and the associated problem definitions.

A list of the Skylab JOPs are given in Table 1. JOPs 1 through 14 were defined for the initial SL-2 flight. JOPs 15 through 17 were added for the second manned flight (SL-3) as a result of the SL-2 quick-look data analysis and crew comments. JOPs 18 through 27 were subsequently added for the final manned flight (SL-4) to add certain observations identified as important during the two previous flights. The latter JOPs also added a program to observe Comet Kohoutek.

Using the available instrument operating modes, the group then defined the data collection process in terms of building blocks, giving the precise time during each orbit when a particular mode for an instrument was to be initiated. In most cases more than one building block was required for each JOP and, in many instances, a given building block was applicable to more than one JOP. These building blocks, the related
pointing instructions, and appropriate photographs for visual aids, were then placed on a single sheet of paper, called a JOP Summary Sheet. These sheets were then used for crew training and subsequently became part of the on-board flight data file. A sample of a JOP summary Sheet is shown in Figure 17. The pointing instructions are listed on the top left side of the sheet, the applicable building blocks on the right, and the visual aid in the lower left hand side of the paper. A similar set of building blocks were defined for use in the unattended and unmanned modes.

In retrospect, it is impossible to visualize flying the ATM mission without employing a JOP procedure. Intelligent flight planning, which is discussed in later paragraphs, would have been extremely difficult and the excellent crew performance that was demonstrated on all three missions would have been seriously hampered.

Flight planning and subsequent execution by the flight and ground crews involved a daily process that demanded timely inputs, efficient operation by all parties, and crisp communication loops. The Joint Observing Program discussed above provided a common language and therefore was the key to achieving the ATM requirements.

In spite of the simplifications afforded by the JOPs, the daily flight planning process was still complicated. The procedures were formulated and iterated several times during pre-flight simulations and some modifications were made even during the initial manned flight. The process described in the following paragraphs represents the final established procedure.

Figure 18 represents the major activities for a typical day, Day N. The day was divided into three shifts; namely, the Summary Flight Planning Shift from midnight to 0800 hrs Central time, the Execute Shift from 0800 hrs to 1600 hrs and the Detail Flight Planning Shift from 1600 hrs to midnight. As the name implies, the Summary Shift personnel produced the Summary Flight Plan (SFP) for the following Day (N + 1). The SFP contained assigned allocations of each crewman's time, time of each day-night cycle, vents schedules, momentum dump inhibits of control moment gyros, video tape recorder schedules, television transmissions to the ground, ground station coverage, star tracker update schedules and general comments to the crew. The negotiation of assignments of blocks of time to each Skylab group of experiments occurred on this shift. To assist them in these negotiations, the ATM representatives used the accomplishments from the previous day's flight, the long range planning inputs from the ATM planning group, the long-range solar forecasts from the National Oceanic and Atmospheric Agency (NOAA), and the results of prior negotiations from the bi-weekly Skylab Science Planning meetings chaired by the Skylab Mission Scientist. The Detail Flight Plans (DFP) for DAY N were transmitted via a teleprinter to the crew during this shift.

Concurrent with the execution of the DAY N flight plan, the ATM Planning Group began preparing their inputs to the next day's Detail Flight Plan at noon, each day. Using the time blocks allocated to the ATM on the DAY N + 1 SFP, the morning television transmission to ground of the video displays, the NOAA solar forecasts and the crew comments from the previous day, the ATM planners determined and scheduled the specific JOPs which they wished executed on the following day. These planning inputs were then transferred to the Detail Flight Planning (DFP) personnel for negotiation on the subsequent shift. The DFP representatives then reviewed and processed the requirements in flight planning terminology to the Flight Activities Officer who subsequently transmitted them to the spacecraft during the following Summary Shift. The Detail Shift also prepared the unattended command plan for those observations that were to be executed via remote commands during the time when the crew was not available.

The various Mission Control Center locations that were involved in the daily ATM flight planning are shown in Figure 19. The Mission Operations Control Room (MOCR) was staffed by the various Skylab functional groups and was under the supervision of the Flight Director. The ATM Activities Officer was the primary ATM voice to the Flight Director on all ATM matters. He was supported by the ATM Science Room and a Staff Support Room. The Science Room was staffed by personnel from each PI organization, NOAA and a Flight Control Division representative. All science questions from either the MOCR or the crew were directed to this group. The Staff Support Room was responsible for all real-time engineering inputs, short-term trend analyses, mission status and all ATM remote commands to the spacecraft.

Representatives in the Planning Room and an offline Data room where quick-look data analyses were conducted, and representatives at the various hardware contractor plants, were in direct support of the Science Room activities.

The Flight Operations Management Room (FOMR), staffed by technical and management personnel from each program element, was in direct support of the Flight Director. This group acted essentially as a real-time change board for rulings on mission requirements. The Skylab Mission Scientist occupied a seat in the FOMR. ATM non-real-time engineering support from the Huntsville Operations Support Center was available through the ATM desk in the FOMR.

SCIENTIFIC RESULTS

All ATM instruments met, and in many instances exceeded, the optical design specifications given in Table 2. Relatively few functional problems were encountered. Whenever a problem did occur, the crew was able to solve it by replacing or repairing the failed system on the next EVA or by utilizing appropriate backup operational modes.

In terms of quantity of data accumulated, Table 3 shows the mission planned quantity as com-
pared to the actual quantity acquired. Table 4 gives the total hours of observing time accumu-
lated in the manned, unattended and unmanned modes. Manned time represents the observation time ac-
cumulated by the flight crews. Unattended time refers to the observation time accumulated via RF
remote commands while the flight crews were on
board but participating in other Skylab experiments
or asleep. Unmanned time was acquired during the
unattended storage periods between the three Skylab
manned flights. It should be noted that only the
S052, S054 and S055 instruments nominally operated
in the unattended and unmanned modes.

Samples of the scientific data collected by the
ATM instruments are shown in Figures 20 through
26. Some of the preliminary findings derived from
these and other similar data are as follows.

Numerous visual changes in coronal structure, such
as the streamers shown opposite the large tran-
sient in Figure 20, have been observed over small-
er increments of time than originally expected.
Whether such changes are a result of dynamic re-
arrangements in the corona, or perspective effects
of particular coronal geometries, will require
further detailed study.

Conventional models of coronal expansion predict
that material is accelerated through the field of
view of the coronagraph in about two days. Pre-
liminary visual examinations of the S052 photo-
graphs fail to show any such material flow, but a
final conclusion cannot be reached until detailed
digital reduction has been accomplished.

Coronal "voids", or dark lanes, amidst coronal
streamers where the electron density is substan-
tially reduced, have been discovered. The mechan-
isms which form, maintain and terminate these
voids are unknown at this time.

The high frequency of coronal transient events
such as that shown in Figure 20 was totally un-
expected.

X-ray photographs of the very hot corona such as
shown in Figure 21 have completely destroyed
earlier concepts of a "quiet, homogeneous corona".
On the contrary, the corona is seen to be composed
of a variety of highly complex structures which
either are directly associated with underlying
photospheric and chromospheric features, as in the
case of active regions, or are indirectly related
to such features. The coronal holes, which appear
in the photographs as areas of little or no X-ray
emission, appear to be the exceptions to this pre-
liminary finding.

New concepts of the total contribution of bright
points are being developed. Such bright points
are shown in Figure 21 as small points of emis-
sions approximately 30 arc-seconds in diameter and
can be clearly seen in the coronal holes and at
the polar regions. The short lifetime of the
bright points, the random occurrence over the
entire disk, the intense brightness and their
similarity to solar flares are all subjects of
extreme interest to the solar physicists.

Mechanisms associated with solar flares erupting
from active regions such as the regions shown in
Figure 22 are being reinvestigated. The S056
X-ray instrument recorded literally hundreds of
X-ray brightenings during the course of the three
Skylab flights. Some cases fit classic flare
theory, some do not.

The effect of chromospheric oscillations on
coronal heating is being questioned since no evi-
dence of such an effect has been found to date in
the ATM data.

Recent correlation with meteorological data have
indicated that passage of the solar-induced
interplanetary magnetic sector boundary affects
the incidence of large storms in the northern
hemisphere of Earth. Since the magnetic sector
boundaries generally coincide with coronal hole
boundaries, the possibility of long-range Earth-
weather predictions appears possible.

SUMMARY

The data collected by the various ATM instruments
is already proving its value in verifying and re-
vising certain conventional theories of solar
physics. The data will furnish a reference base
for future analyses and further experimental work
in solar physics for years to come. This, of
course, was the major overall objective of the
project. But other project accomplishments will
certainly prove worthwhile precedents for future
missions. Specifically, they are:

1. Formulation and successful implementation of
the Joint Observing Program concept.

2. Formulation and successful implementation of
the coordinated observing program with worldwide
ground-based observatories.

3. Outstanding functional and optical perform-
ance of all instruments.


6. High quantitative yield of scientific data.

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