NRL Report 7724

A Pictorial Review of OSO 7 White Light Coronagrams and Extreme Ultraviolet Heliograms

R. T. SEAL, D. E. ROBERTS, AND J. D. WHITNEY

Rocket Spectroscopy Branch
Space Science Division

April 11, 1974

NAVAL RESEARCH LABORATORY
Washington, D.C.

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Coronagraph

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Since September 29, 1971, two NRL experiment instruments aboard Orbiting Solar Observatory (OSO 7) have been receiving daily images of the solar disk in the far ultraviolet, which is invisible from the ground, and of the white light solar corona, which is seen only during eclipses. This report gives a brief description of the instruments and shows a series of daily pictures covering one solar rotation. Besides daily changes, the series shows examples of other newly observed phenomena, such as close passage of the planet Jupiter and the moon, ultraviolet coronal holes, and a transient coronal event.

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CONTENTS

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INTRODUCTION

On September 29, 1971, an Orbiting Solar Observatory (OSO) (Fig. 1) was launched from Cape Kennedy carrying into orbit around earth two NRL solar-oriented experiments: a white light coronagraph and an extreme ultraviolet (xuv) heliograph. Both instruments are still working after more than 2 years of operation, and during that time NRL personnel have been moniotring daily the solar corona from 3 to 10 solar radii as well as the activity on the solar disk in the far ultraviolet. The group has obtained ultraviolet images of the sun and its white light corona at the rate of 8 to 10 pictures per day, totaling over 7500 pictures. It is the first time that it has been possible to watch the corona from day to day rather than at the rare moments allowed by natural eclipses.

The objective of this report is not to give an analysis but a representative pictorial displav of the images received. To accomplish this we have prepared a series of pictures of one set per day for 29 days for one Carrington rotation (360° rotation of the sun). These pictures show the rotation, formation, and dissipation of coronal streamers and active regions on the solar disk.

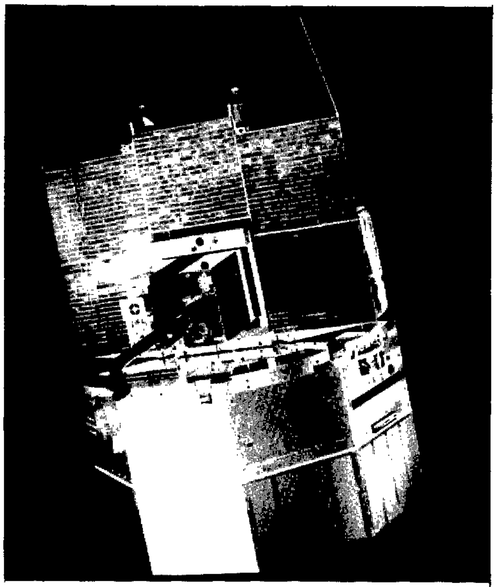


Fig. 1 — OSO 7 spacecraft. The instrument case containing the white light coronagraph and xuv instrument is mounted in the spacecraft "sail," the surface of which is covered with solar cells and kept pointed at the sun. Underneath, the large octagonal wheel, which contains spacecraft batteries, electronics, and several small instruments, rotates continually to provide inertial stability. The spar that holds the coronagraph occulting disks can be seen projecting forward. The xuv instrument looks out between two rectangular light shields just above the base of the spar.

Manuscript submitted January 25, 1974.

INSTRUMENT DESCRIPTION

White Light Coronagraph

The white light coronagraph is similar to one designed for ground-based use by the French astronomer Lyot and modified by Evans of Sacramento Peak Observatory. The NRL instrument artificially eclipses the sun by means of three small disks in tandem supported at the end of a spar 30 in. (76.2 cm) in front of a camera. At orbiting altitudes where the sky is black, the artificial eclipse by these occulting disks creates a situation similar to that of a lunar eclipse, enabling one to see the sun's faint corona without the need of waiting for a natural eclipse.

For one to photograph the sun's outer corona, which is about 10^{-9} the brightness of the sun, a very special camera is required because even a small amount of stray sunlight will swamp the faint image of the corona. Figure 2 shows the optical system of this camera, which was designed to photograph a very dim image and suppress the unwanted stray light due to scattering and diffraction of sunlight from the occulting disks and the camera. The three external occulting disks cast a circular shadow onto the objective aperture and at the same time minimize the amount of sunlight diffracted into the shadow. Each disk intercepts the diffracted light from the one preceding, and the residual diffracted light that escapes from the edge of the final disk and enters the objective lens in the shadow is imaged onto an opaque stop behind the field lens. Sunlight diffracted from the edge of the objective aperture is imaged onto an aperture stop in a relay lens that forms the final image of the corona. Together, the two stops prevent diffracted light from reaching the final image at the focal plane.

An auxiliary optical system projects an attenuated solar image into the center of the coronal image at the same magnification as the main optical system. This image serves as an intensity calibration and spatial reference point.

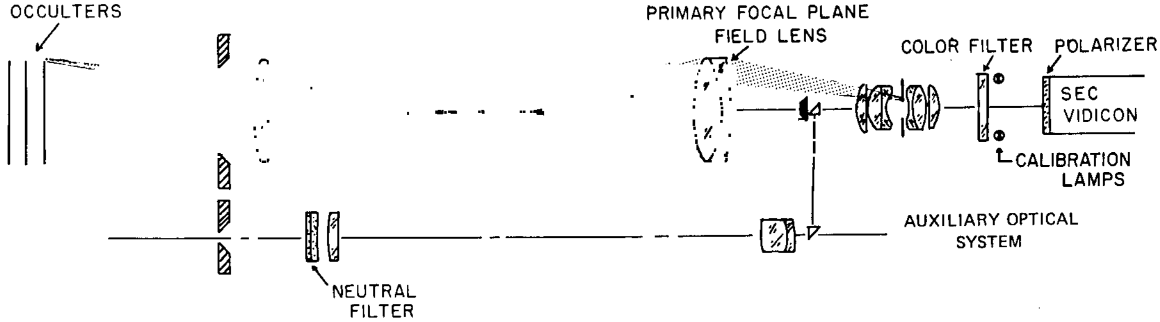


Fig. 2 — The white light coronagraph optical system. Diffracted sunlight originating at the edges of the occulting disk and entrance aperture is imaged onto internal stops and does not reach the focal plane. The stippled areas indicate the ray paths.

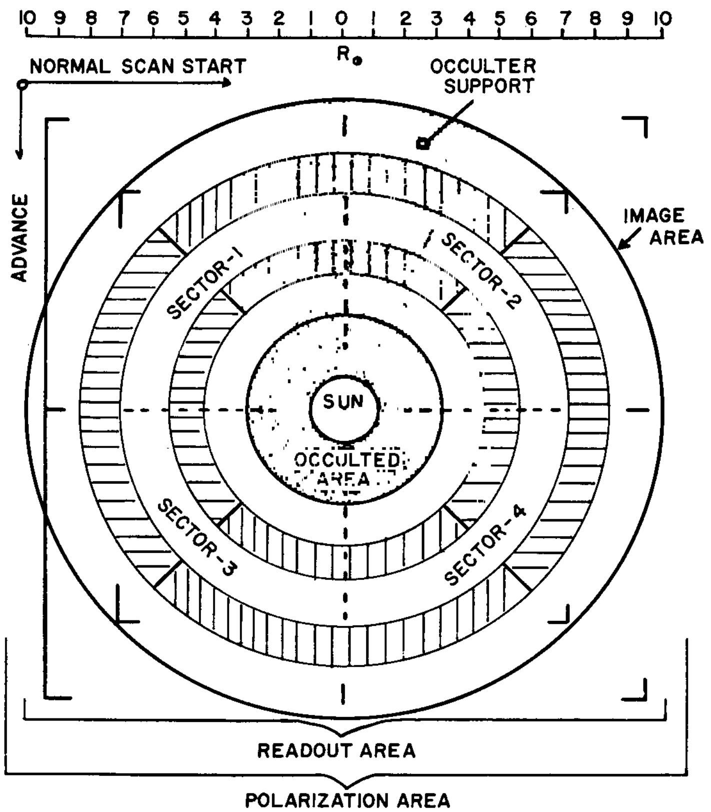
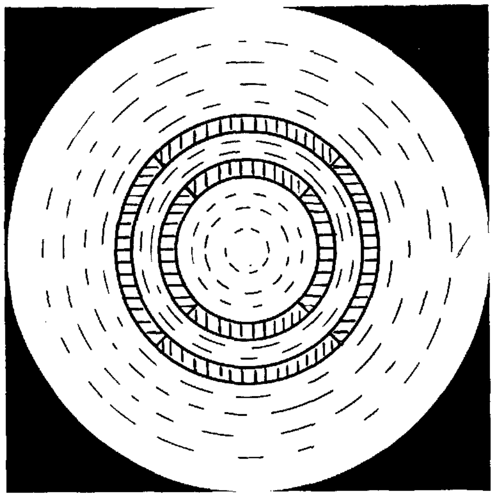
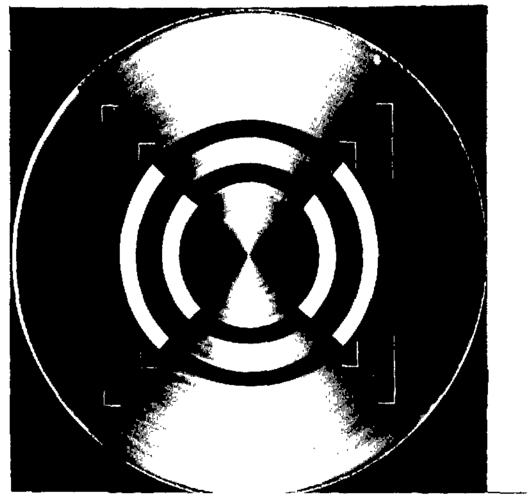


Fig. 3 — A composite sketch of the coronagraph's image area on the vidicon faceplate. The top scale shows the dimensions of the field in solar radii $R_{\odot}$. Other features such as reticle marks, the occulated area of the image, and the placement of optical polarizer segments are shown. The "polarization area" at the bottom of the sketch refers to the image area of the vidicon at which point the old image is completely erased by an electronic procedure (polarization) to prepare the vidicon for the next exposure.

Figure 3 shows schematically the configuration of the faceplate of the coronagraph's vidicon camera tube, which receives the image of the corona. The dark area in the center extending to approximately 3 solar radii represents the image of the occulting disks and their support. The vidicon faceplate is covered with a "concentric" polarizer, which at any point admits light polarized perpendicular to a field radius. At approximately 3 and 7 solar radii this is replaced by a multisector pattern of linear polarizers as shown. Engraved on the polarizer plate is a reticle pattern for spatial reference. Figure 4 shows a photograph of the polarizer using 100% linearly polarized light.

The camera tube, whose flat-fiber-optics faceplate lies in the coronagraph's focal plane, is a Westinghouse WX-31189N secondary electron conduction (SEC) vidicon storage (a





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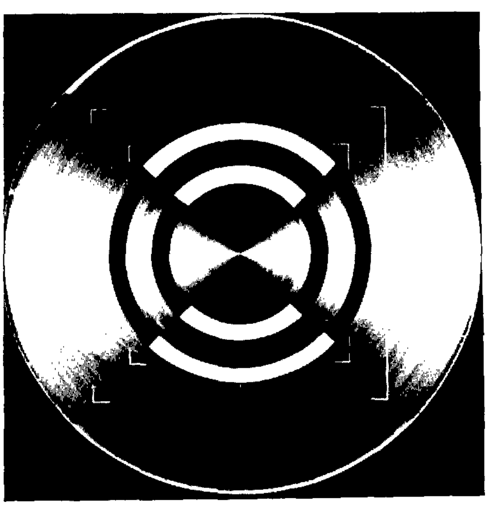


(c)

Fig. 4 — The optical polarizer showing the polarization direction of various segments and the placement of reticle lines. (a) Three zones of concentric polarizers interrupted by two annular rings of linear polarizers, which are divided into four segments of different orientation: horizontal and vertical direction of maximum transmission. (b) Illumination of the polarizer with 100% linear polarized light, direction of $\overline{E}_{max}$, horizontal. (c) Illumination of the polarizer with 100% linear polarized light, direction of $\overline{E}_{max}$, vertical.

tube. The faceplate is a circle with a 1-in. (2.54 cm) diameter in which a 0.70-in. (177.8 cm) square is sampled in 256 lines, each line having 256 picture elements, to form a picture of 65,536 points. The total field of view is 5°, and each picture element represents 1.25 arcmin. Because of the extremely high sensitivity of the SEC vidicon tube, the image of the corona, which produces an illumination of only 10^{-4} ft-c, can be integrated and stored on the vidicon target with only a few seconds of exposure time. The electric analog of the image will remain stored on the target indefinitely, until it is read into the spacecraft tape recorder as a digital data stream. From here it is transmitted to the ground at a much faster rate when the satellite passes over a ground station.

Extreme Ultraviolet Heliograph Coronagraph

The OSO 7 xuv heliograph (Fig. 5) is a simple reflective telescope of 750-mm focal length. The instrument has no spectral dispersion but depends on the transmission characteristics of thin aluminum films, and other system elements, for limitation of the response to a broad band of wavelengths that spans roughly the region from 17 to 63 nm. An image of the sun as it appears in this wavelength band is analyzed by an image dissector system, then digitized, recorded, and telemetered back to earth during passes over ground stations.

In the extreme ultraviolet it is not necessary to use an occulting disk to shield the detector from the brilliant direct rays of the photospheric disk because the photosphere (at a temperature of 6000 K) does not emit at these very short wavelengths. Only the higher, and much hotter, regions of the solar atmosphere, namely the upper chromosphere and inner corona, are at sufficiently high temperatures (50,000 to 1,000,000 K) to excite the very-high-energy xuv radiations. With this instrument it is possible, therefore, to view the radiant-energy distribution of the inner corona over the solar disk itself as well as in the sky beyond the limb.

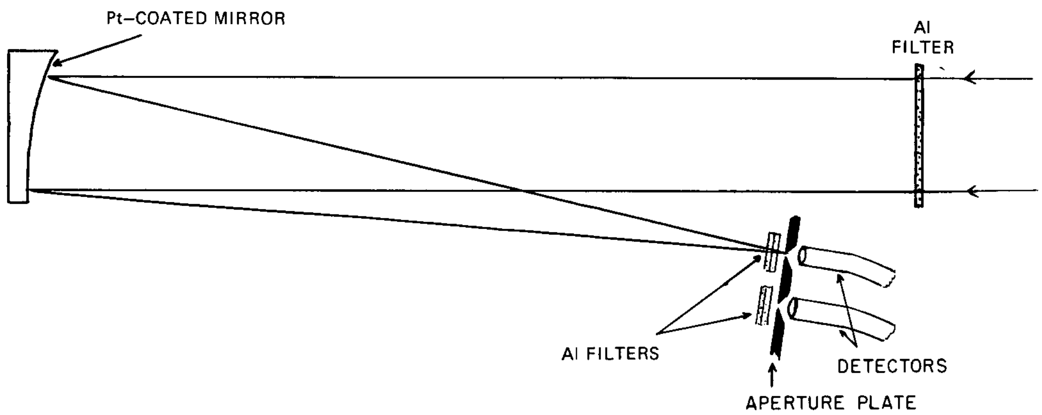


Fig. 5 — Optical diagram of the xuv instrument. The sun is imaged on the aperture plate and scanned by movement of the entire optical system. Signal intensities are recorded by the ultraviolet-sensitive capillary detectors.

It is estimated that about 30% of the total signal is chromospheric; that is, it is emitted from the chromosphere which lies very close to the solar surface we see in visible light. The light is mostly from neutral and singly ionized helium and is seen as a nearly uniform emission on the quiet disk. The remaining signal comes from high-temperature coronal ions that are concentrated in the bright condensations overlying photospheric active regions. Estimates of the height of these condensations in the solar atmosphere can be made from extension above the limb at the time of passage and also from projection geometry because we frequently observe brightenings above the limb 2 or 3 days before a photospheric spot group is rotated onto the east limb from the back side of the sun, or after it has disappeared in the west.

DATA DESCRIPTION

The group of pictures from December 19, 1972, to January 16, 1973, depict one solar rotation (Fig. 6). The period of a solar rotation is approximately 27 days. Thus, in the xuv images, a spot near the center of the disk will disappear at the edge in about 1 week, then rotate across the back of the sun and reappear at the opposite edge in about 2 weeks, and 1 week later again appear near the center of the disk. The sun's rotation is from west to east, thus a spot on the hemisphere that faces us will be carried across the disk from east to west with respect to direction in the sky.

Pictorial evidence of a 27-day solar rotation can be seen in the xuv heliograms. On the heliogram taken December 23, 1972, three vertical bright spots can be seen in the center of the disk; on about December 30 (7 days later) they can be observed on the west limb, having rotated 90°. On December 29, 1972, another bright spot can be seen on the east limb of the disk; and 14 days later it had rotated 180° to the west limb.

Solar rotation can also be seen in the white light coronagrams. On December 20, 1972, a bright streamer can be seen in the southwest; 14 days later, on January 3, 1973, the streamer has rotated around the back side of the sun and reappears in the southeast. By January 16, 1973, the streamer has returned to the southwest, showing a rotation of 360° in approximately 27 days.

As one observes the white light coronagrams, a slight difference in image quality can be noticed between images taken on different days. This is due to data compression, later referred to as corridor. Without data compression the entire 65,536 data points are read out on a scale of 1 to 128 brightness units and recorded onto the logic recorder. This requires 44 min readout time and limits the data to one picture per orbit. By using a corridor mode of data compression, the readout time is shortened, thus allowing more pictures per orbit and a closer look at a rapidly changing corona. However, there is a slight loss of intensity and spatial resolution in corridor mode.

There are three corridor modes available: ±3, ±6, and ±12 units of brightness. By preselecting a corridor, the number of data points required to construct a picture may be reduced. This reduction of data points is accomplished by writing out onto the tape recorder the value of the intensity point only if it differs from the previous value by more than the preselected corridor; otherwise it is skipped.

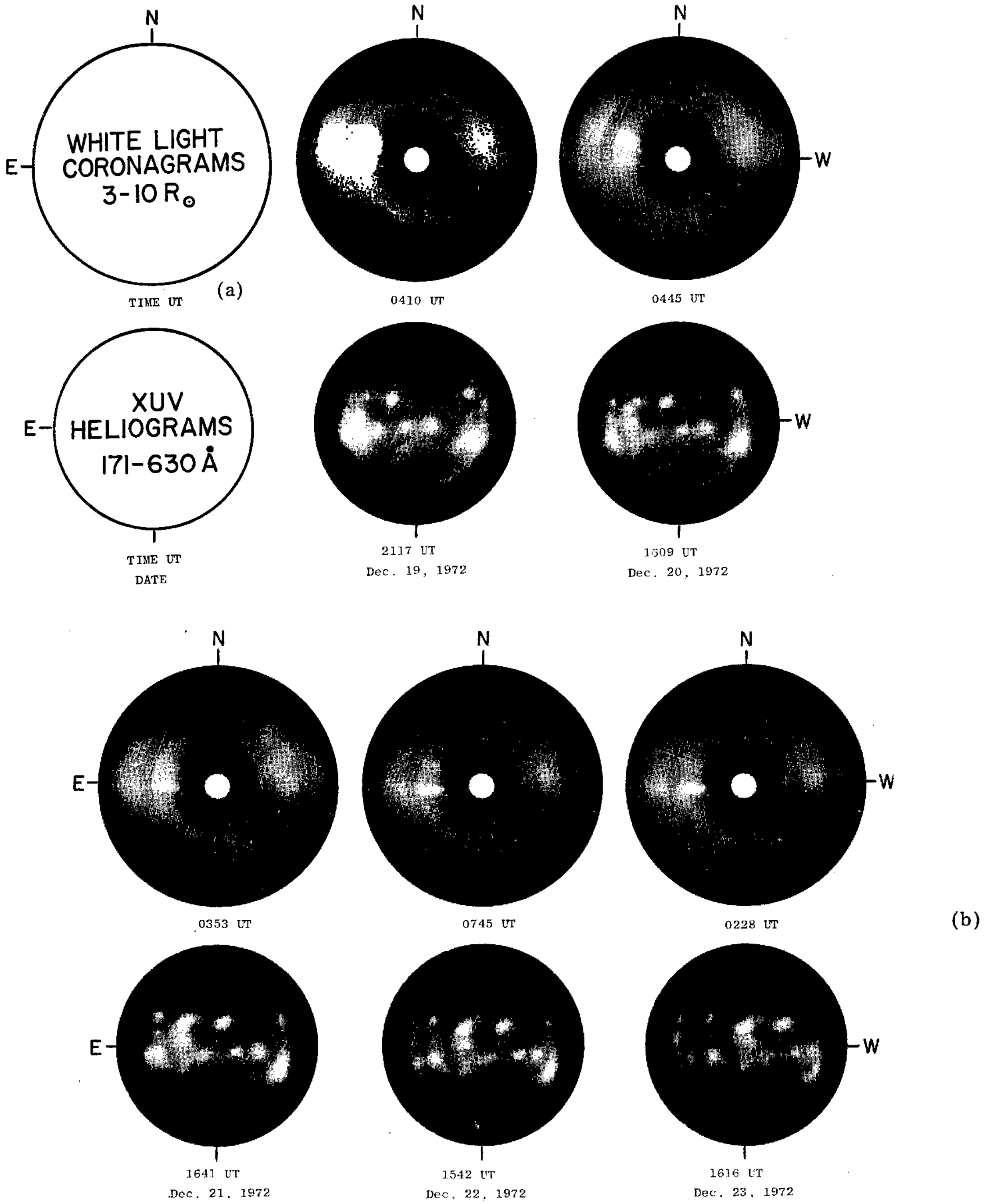
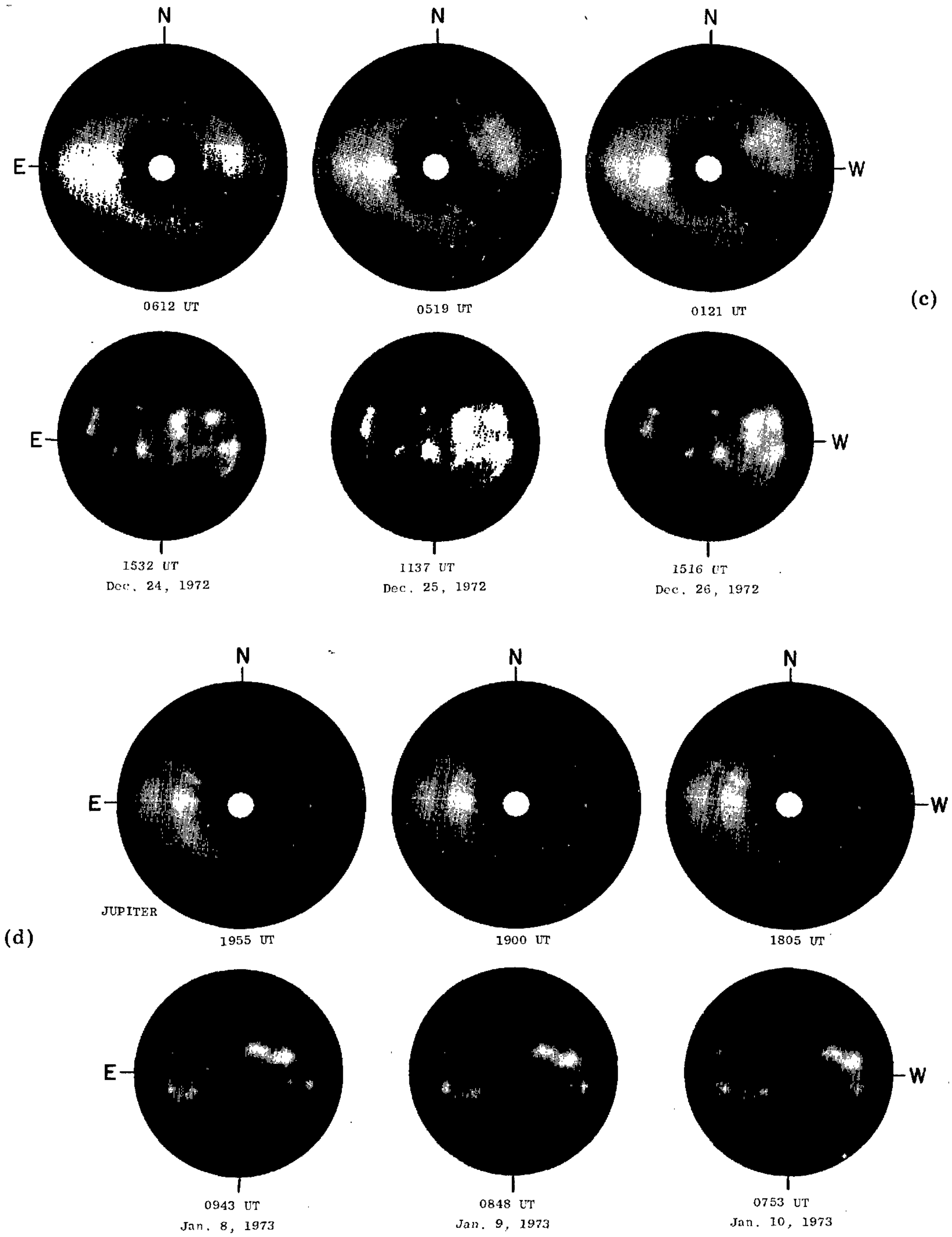


Fig. 6 — The top images are daily white light coronagrams recorded from 3 to 10 solar radii during one solar rotation. The bottom row of daily images was recorded in xuv light of wavelength 17 to 63 nm during one solar rotation. These images show the solar surface and patches of corona which lie above active regions.



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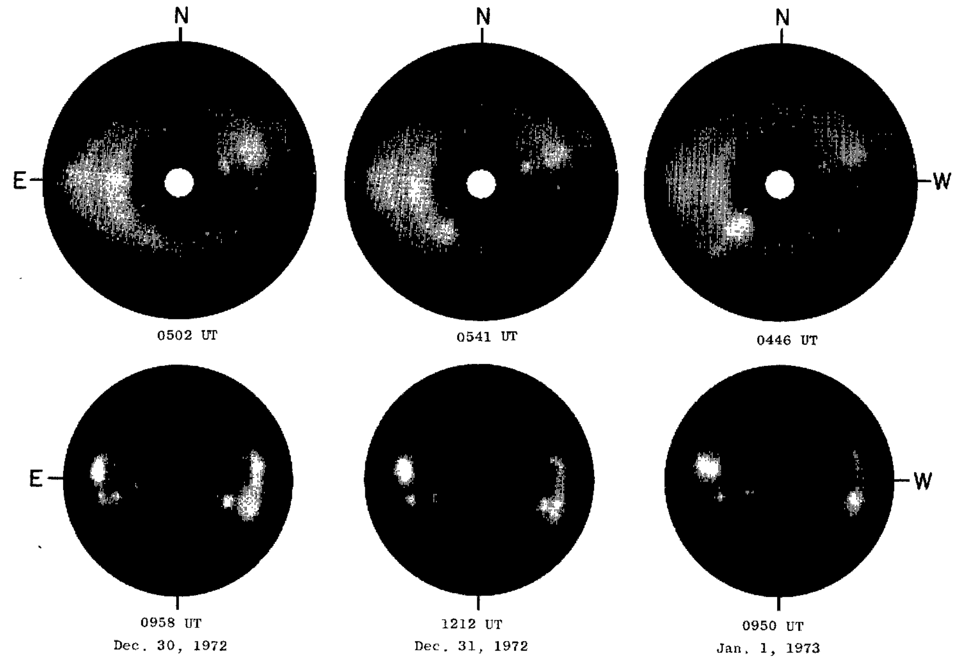

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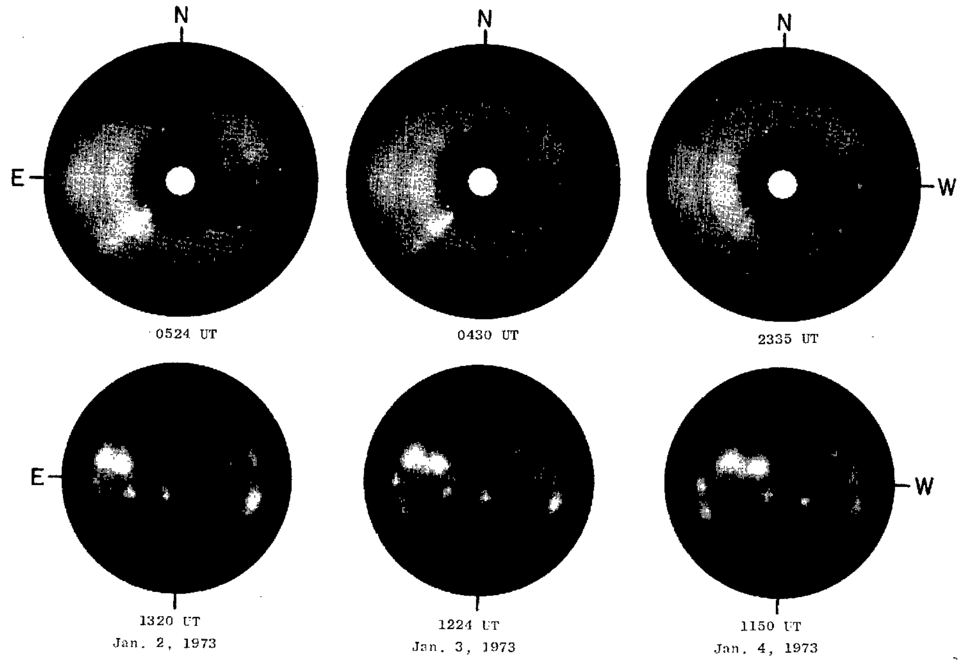

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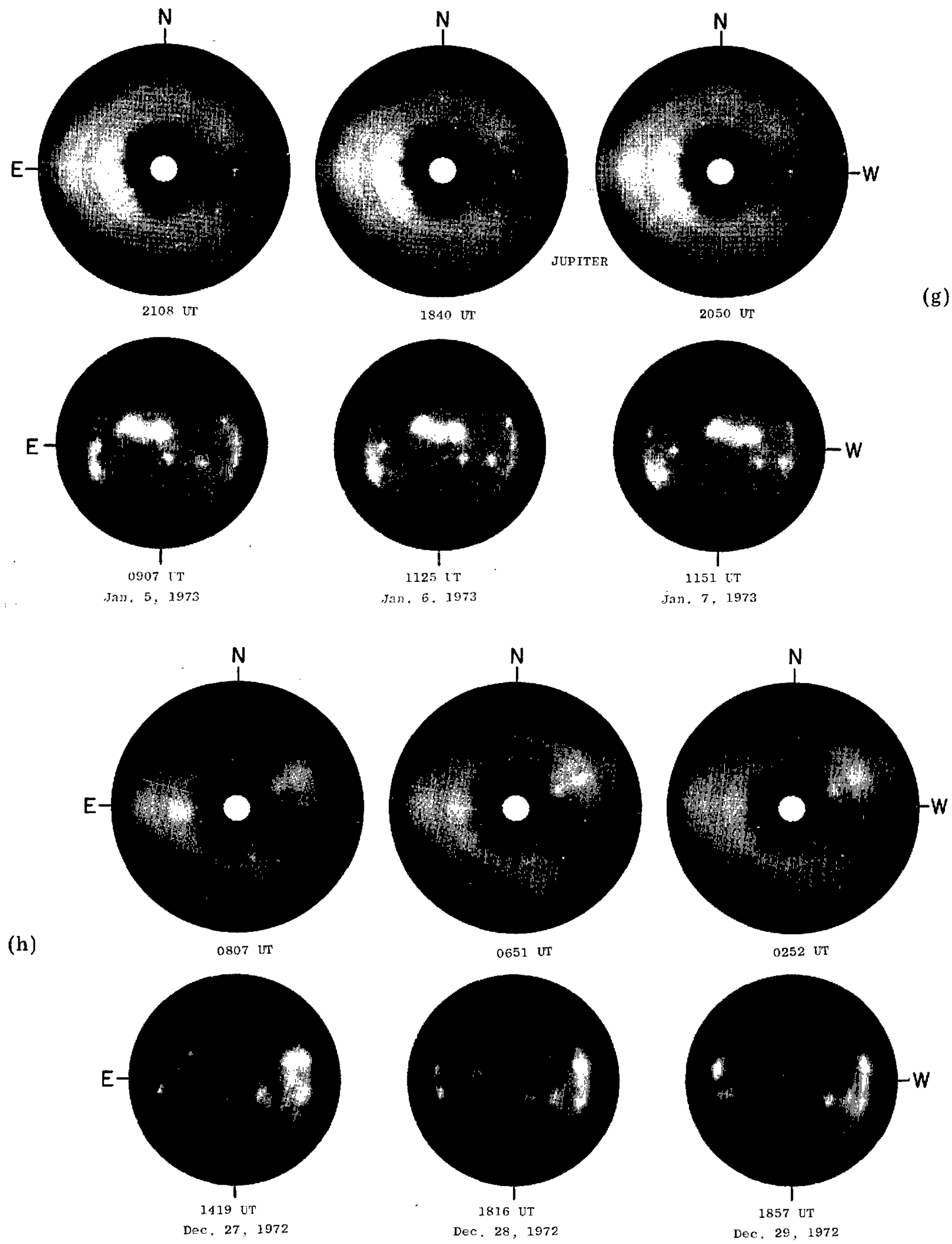

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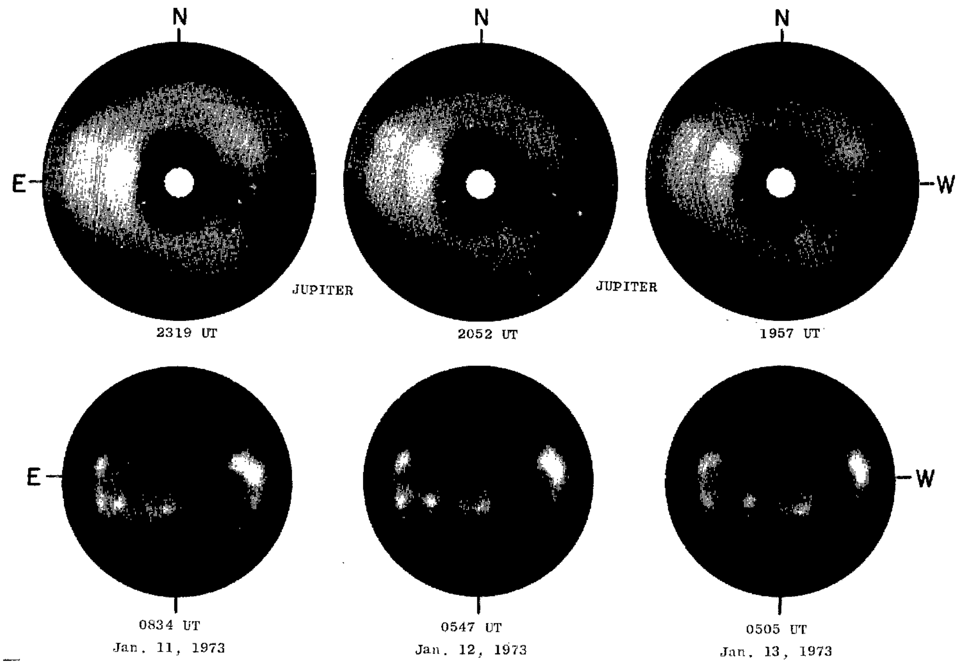

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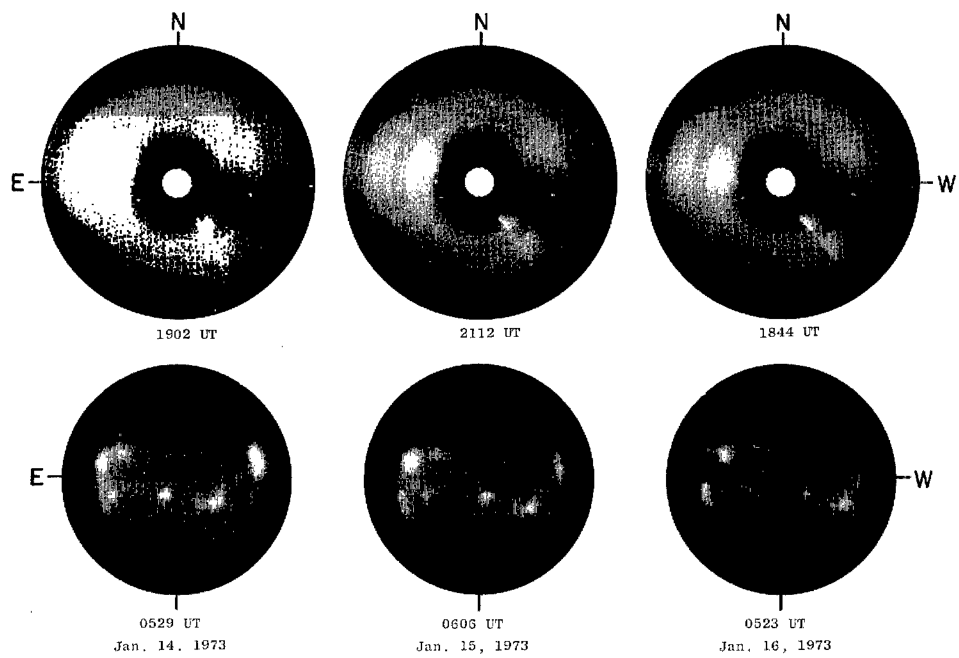

(j)

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The December 21, 1972 image was taken in 0 corridor (no data compression) and required 44 min of readout time; the December 22, 1972 image was taken in 12 corridor with 9 min of readout time; the December 23, 1972 image was taken in 6 corridor with 24 min of readout time; and the January 2, 1973 image was taken in 3 corridor with 35 min readout time.

Of particular interest is the corona series from December 24, 1972, to December 29, 1972. The bright streamer seen in the east shows an expansion in width reaching a maximum on December 26 and completely dissipating itself by December 29. One can imagine this streamer actually exploding and dissipating into space. To realize the enormous size of this streamer, the December 24 picture shows the streamer extending to approximately 10 solar radii (4.32 million miles), or 1/20 of the distance to earth. The width of the streamer at 4 solar radii is equal to approximately 48 earth diameters. On December 26, the width of the streamer at 4 solar radii had increased to approximately 108 earth diameters. Many of these streamer eruptions or explosions have been recorded during the past 2 years by the coronagraph.

From January 7 through January 12, 1973, the planet Jupiter (—1.4 magnitude) passed through the coronagraph's field of view. It can be seen moving from east to west as it passes on the far side of the sun (superior conjunction). The image is lost on January 9 and 10 as the planet passes behind the occulted area of the picture but emerges again on January 11.

Still another capability of the coronagraph is to record a preselected area of the corona. This is accomplished by dividing the recorded image into four 90° sectors. (See Fig. 3). Each sector may be individually recorded as often as needed. Figure 7 shows an example of this mode of operations. On January 16, 1972, the moon, traveling from west to east, passed within 1° of the sun. To follow this passage, several pictures were taken in each sector. Sector 1 in the northwest was taken at 0403 UT, sector 2 in the southwest was taken at 0542 UT, sector 4 in the southeast consists of two pictures taken at 1038 and 1355 UT, and sector 3 in the northeast was taken at 1513 UT. The resulting picture is a computerized composite of these different exposures.

On December 14, 1971, a massive eruption from the sun was observed traveling through its outer corona. (See Fig. 8.) During the explosive event, clouds of hot gas, some 40 times the size of earth, blasted away from the solar surface at speeds up to 600 miles per second. These clouds are visible on the east side of the picture.

Returning to the xuv data, Fig. 9 shows a single xuv picture of the sun from OSO 7. Spatial resolution of the system is 1 by 1.25 arcmin and is determined by the mechanical raster of the OSO spacecraft. In this figure the picture element size is considerably smaller (about 19 by 19 arcsec) than the spatial resolution element. This effect (matrix expansion) is introduced during processing. Contrast enhancement has also been employed. Bright regions in the picture represent hot, dense regions of the solar atmosphere. Darker areas correspond to cooler, and sometimes less dense, regions. Note the extended dark region near the top center (solar north pole) of the solar disk. Large regions of depressed xuv emission such as this one constitute a new class of coronal features of great current interest known as "coronal holes." They are thought to represent regions of open magnetic field configuration and may be the source of high velocity solar wind streams sometimes observed in the vicinity of earth. The small black spot at bottom center is due to a transmission dropout in the telemetry data stream.

SUMMARY

This report has presented only a small fraction of the total data available. We now have on hand for the first time a 2-year daily coverage of the sun's outer corona, which had preciously been glimpsed only during eclipses. A 2-year continuous record of the sun's xuv corona is also on hand. From this massive collection of data it is hoped that solar scientists will develop a better understanding of the sun.

ACKNOWLEDGMENTS

The success of a major experiment carried in such a vehicle as OSO 7 depends on the efforts of many individuals. Among those who contributed to the NRL experiment are R. Tousey, M. J. Koomen, D. J. Michels, C. R. Detwiler, G. E. Brueckner, D. M. Packer, I.G. Packer, R. A. Howard, H. W. Cooper, J. K. Smith, R. K. Chaimson, W. H. Funk, E. Spiller, and J. P. MacCormack.

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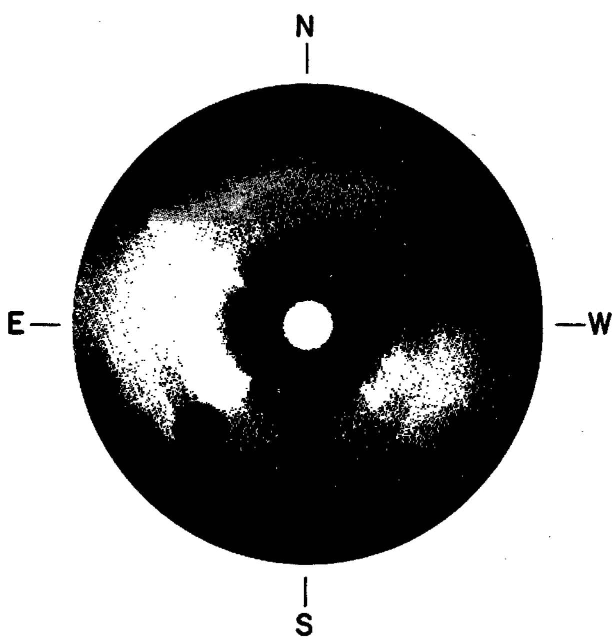

Fig. 7 — A multiple exposure in the white light coronagram showing the moon passing nearly in front of the sun. The moon is silhouetted against the corona, but some features of its surface can be seen by light reflected to it from the sunlit earth.

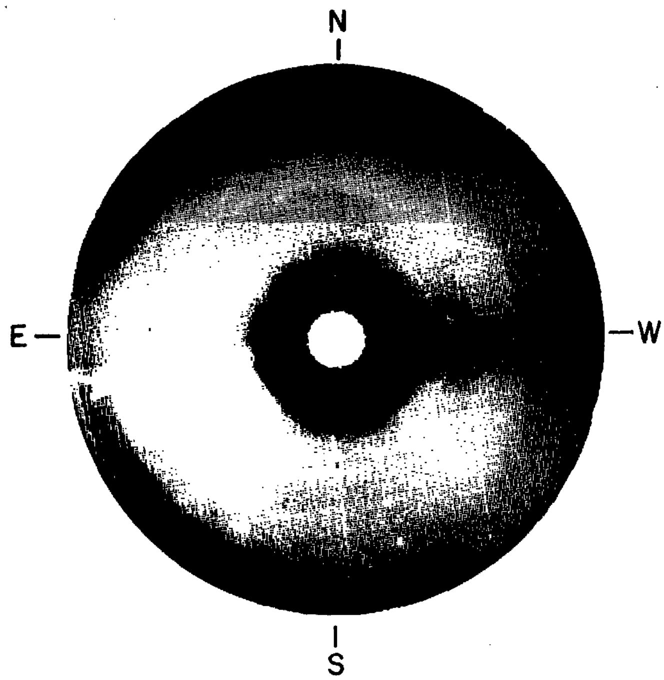

Fig. 8 — Clouds of hot gas being expelled to the southeast from the surface of the sun on December 14, 1971.

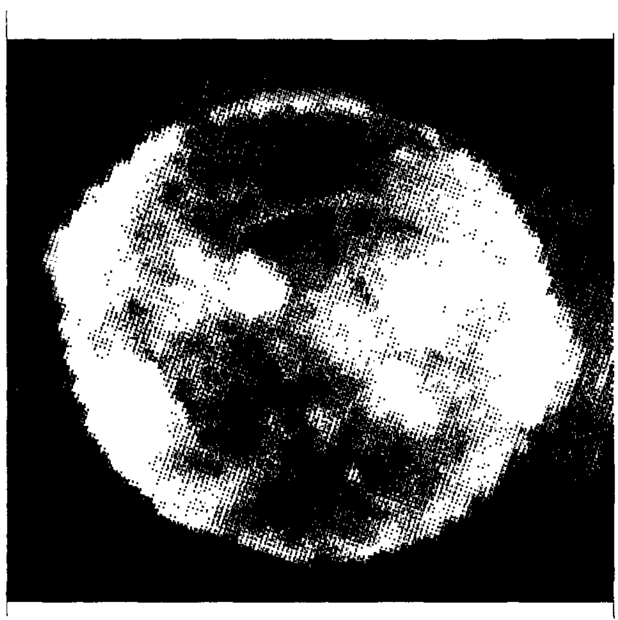

Fig. 9 — An xuv image of the sun showing bright patches of corona lying above many active regions

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Since September 29, 1971, two NRL experiment instruments aboard Orbiting Solar Observatory (OSO 7) have been receiving daily images of the solar disk in the far ultraviolet, which is invisible from the ground, and of the white light solar corona, which is seen only during eclipses. This report gives a brief description of the instruments and shows a series of daily pictures covering one solar rotation. Besides daily changes, the series shows examples of other newly observed phenomena, such as close passage of the planet Jupiter and the moon, ultraviolet coronal holes, and a transient coronal event.

CONTENTS

A PICTORIAL REVIEW OF OSO 7 WHITE LIGHT CORONAGRAMS AND EXTREME ULTRAVIOLET HELIOGRAMS

INTRODUCTION

On September 29, 1971, an Orbiting Solar Observatory (OSO) (Fig. 1) was launched from Cape Kennedy carrying into orbit around earth two NRL solar-oriented experiments: a white light coronagraph and an extreme ultraviolet (xuv) heliograph. Both instruments are still working after more than 2 years of operation, and during that time NRL personnel have been moniotring daily the solar corona from 3 to 10 solar radii as well as the activity on the solar disk in the far ultraviolet. The group has obtained ultraviolet images of the sun and its white light corona at the rate of 8 to 10 pictures per day, totaling over 7500 pictures. It is the first time that it has been possible to watch the corona from day to day rather than at the rare moments allowed by natural eclipses.

The objective of this report is not to give an analysis but a representative pictorial displav of the images received. To accomplish this we have prepared a series of pictures of one set per day for 29 days for one Carrington rotation (360° rotation of the sun). These pictures show the rotation, formation, and dissipation of coronal streamers and active regions on the solar disk.

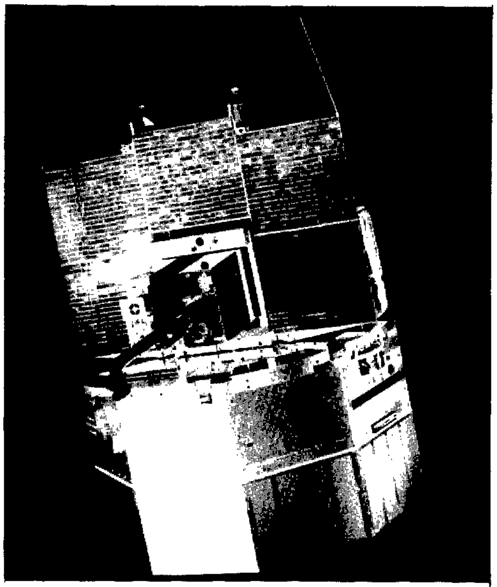


Fig. 1 — OSO 7 spacecraft. The instrument case containing the white light coronagraph and xuv instrument is mounted in the spacecraft "sail," the surface of which is covered with solar cells and kept pointed at the sun. Underneath, the large octagonal wheel, which contains spacecraft batteries, electronics, and several small instruments, rotates continually to provide inertial stability. The spar that holds the coronagraph occulting disks can be seen projecting forward. The xuv instrument looks out between two rectangular light shields just above the base of the spar.

Manuscript submitted January 25, 1974.

INSTRUMENT DESCRIPTION

White Light Coronagraph

The white light coronagraph is similar to one designed for ground-based use by the French astronomer Lyot and modified by Evans of Sacramento Peak Observatory. The NRL instrument artificially eclipses the sun by means of three small disks in tandem supported at the end of a spar 30 in. (76.2 cm) in front of a camera. At orbiting altitudes where the sky is black, the artificial eclipse by these occulting disks creates a situation similar to that of a lunar eclipse, enabling one to see the sun's faint corona without the need of waiting for a natural eclipse.

For one to photograph the sun's outer corona, which is about 10^{-9} the brightness of the sun, a very special camera is required because even a small amount of stray sunlight will swamp the faint image of the corona. Figure 2 shows the optical system of this camera, which was designed to photograph a very dim image and suppress the unwanted stray light due to scattering and diffraction of sunlight from the occulting disks and the camera. The three external occulting disks cast a circular shadow onto the objective aperture and at the same time minimize the amount of sunlight diffracted into the shadow. Each disk intercepts the diffracted light from the one preceding, and the residual diffracted light that escapes from the edge of the final disk and enters the objective lens in the shadow is imaged onto an opaque stop behind the field lens. Sunlight diffracted from the edge of the objective aperture is imaged onto an aperture stop in a relay lens that forms the final image of the corona. Together, the two stops prevent diffracted light from reaching the final image at the focal plane.

An auxiliary optical system projects an attenuated solar image into the center of the coronal image at the same magnification as the main optical system. This image serves as an intensity calibration and spatial reference point.

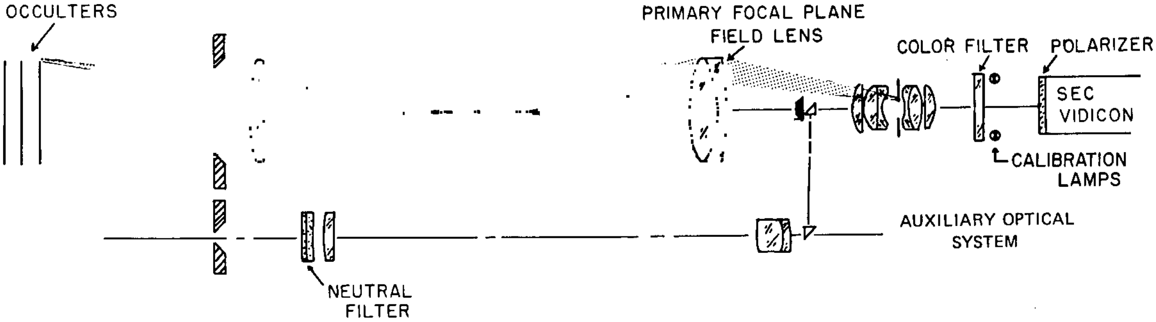


Fig. 2 — The white light coronagraph optical system. Diffracted sunlight originating at the edges of the occulting disk and entrance aperture is imaged onto internal stops and does not reach the focal plane. The stippled areas indicate the ray paths.

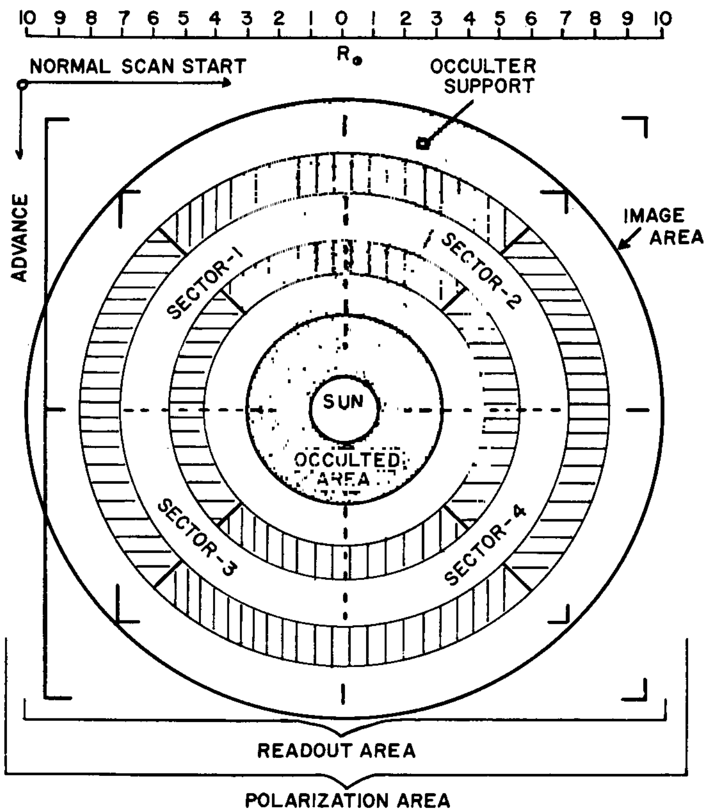
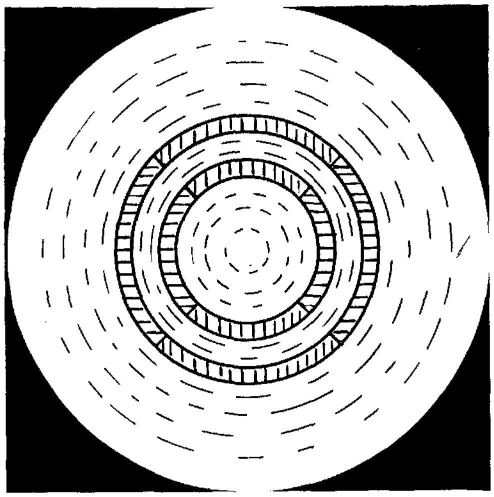
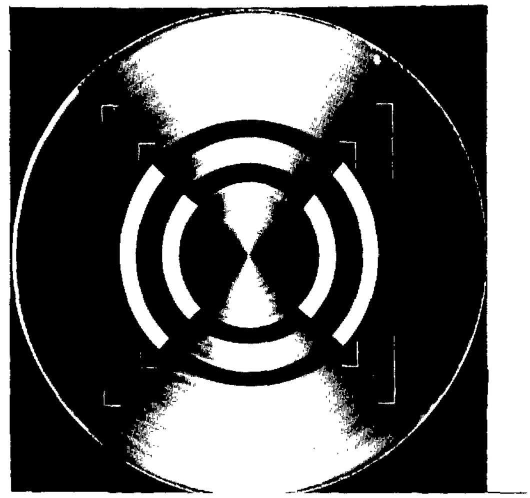


Fig. 3 — A composite sketch of the coronagraph's image area on the vidicon faceplate. The top scale shows the dimensions of the field in solar radii $R_\odot$. Other features such as reticle marks, the occulated area of the image, and the placement of optical polarizer segments are shown. The "polarization area" at the bottom of the sketch refers to the image area of the vidicon at which point the old image is completely erased by an electronic procedure (polarization) to prepare the vidicon for the next exposure.

Figure 3 shows schematically the configuration of the faceplate of the coronagraph's vidicon camera tube, which receives the image of the corona. The dark area in the center extending to approximately 3 solar radii represents the image of the occulting disks and their support. The vidicon faceplate is covered with a "concentric" polarizer, which at any point admits light polarized perpendicular to a field radius. At approximately 3 and 7 solar radii this is replaced by a multisector pattern of linear polarizers as shown. Engraved on the polarizer plate is a reticle pattern for spatial reference. Figure 4 shows a photograph of the polarizer using 100% linearly polarized light.

The camera tube, whose flat-fiber-optics faceplate lies in the coronagraph's focal plane, is a Westinghouse WX-31189N secondary electron conduction (SEC) vidicon storage (a





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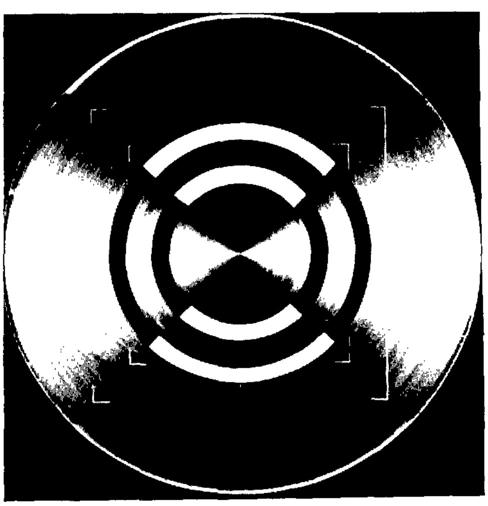


(c)

Fig. 4 — The optical polarizer showing the polarization direction of various segments and the placement of reticle lines. (a) Three zones of concentric polarizers interrupted by two annular rings of linear polarizers, which are divided into four segments of different orientation: horizontal and vertical direction of maximum transmission. (b) Illumination of the polarizer with 100% linear polarized light, direction of $\overline{E}_{max}$, horizontal. (c) Illumination of the polarizer with 100% linear polarized light, direction of $\overline{E}_{max}$, vertical.

tube. The faceplate is a circle with a 1-in. (2.54 cm) diameter in which a 0.70-in. (177.8 cm) square is sampled in 256 lines, each line having 256 picture elements, to form a picture of 65,536 points. The total field of view is 5°, and each picture element represents 1.25 arcmin. Because of the extremely high sensitivity of the SEC vidicon tube, the image of the corona, which produces an illumination of only 10^{-4} ft-c, can be integrated and stored on the vidicon target with only a few seconds of exposure time. The electric analog of the image will remain stored on the target indefinitely, until it is read into the spacecraft tape recorder as a digital data stream. From here it is transmitted to the ground at a much faster rate when the satellite passes over a ground station.

Extreme Ultraviolet Heliograph Coronagraph

The OSO 7 xuv heliograph (Fig. 5) is a simple reflective telescope of 750-mm focal length. The instrument has no spectral dispersion but depends on the transmission characteristics of thin aluminum films, and other system elements, for limitation of the response to a broad band of wavelengths that spans roughly the region from 17 to 63 nm. An image of the sun as it appears in this wavelength band is analyzed by an image dissector system, then digitized, recorded, and telemetered back to earth during passes over ground stations.

In the extreme ultraviolet it is not necessary to use an occulting disk to shield the detector from the brilliant direct rays of the photospheric disk because the photosphere (at a temperature of 6000 K) does not emit at these very short wavelengths. Only the higher, and much hotter, regions of the solar atmosphere, namely the upper chromosphere and inner corona, are at sufficiently high temperatures (50,000 to 1,000,000 K) to excite the very-high-energy xuv radiations. With this instrument it is possible, therefore, to view the radiant-energy distribution of the inner corona over the solar disk itself as well as in the sky beyond the limb.

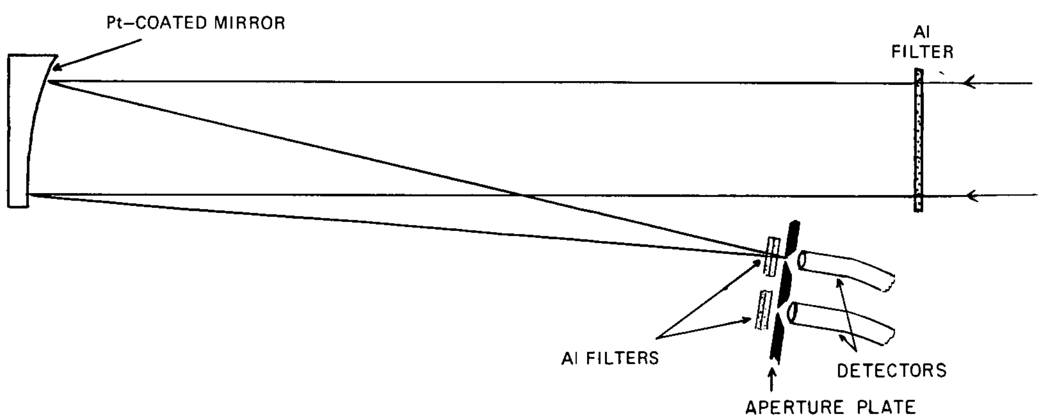


Fig. 5 — Optical diagram of the xuv instrument. The sun is imaged on the aperture plate and scanned by movement of the entire optical system. Signal intensities are recorded by the ultraviolet-sensitive capillary detectors.

It is estimated that about 30% of the total signal is chromospheric; that is, it is emitted from the chromosphere which lies very close to the solar surface we see in visible light. The light is mostly from neutral and singly ionized helium and is seen as a nearly uniform emission on the quiet disk. The remaining signal comes from high-temperature coronal ions that are concentrated in the bright condensations overlying photospheric active regions. Estimates of the height of these condensations in the solar atmosphere can be made from extension above the limb at the time of passage and also from projection geometry because we frequently observe brightenings above the limb 2 or 3 days before a photospheric spot group is rotated onto the east limb from the back side of the sun, or after it has disappeared in the west.

DATA DESCRIPTION

The group of pictures from December 19, 1972, to January 16, 1973, depict one solar rotation (Fig. 6). The period of a solar rotation is approximately 27 days. Thus, in the xuv images, a spot near the center of the disk will disappear at the edge in about 1 week, then rotate across the back of the sun and reappear at the opposite edge in about 2 weeks, and 1 week later again appear near the center of the disk. The sun's rotation is from west to east, thus a spot on the hemisphere that faces us will be carried across the disk from east to west with respect to direction in the sky.

Pictorial evidence of a 27-day solar rotation can be seen in the xuv heliograms. On the heliogram taken December 23, 1972, three vertical bright spots can be seen in the center of the disk; on about December 30 (7 days later) they can be observed on the west limb, having rotated 90°. On December 29, 1972, another bright spot can be seen on the east limb of the disk; and 14 days later it had rotated 180° to the west limb.

Solar rotation can also be seen in the white light coronagrams. On December 20, 1972, a bright streamer can be seen in the southwest; 14 days later, on January 3, 1973, the streamer has rotated around the back side of the sun and reappears in the southeast. By January 16, 1973, the streamer has returned to the southwest, showing a rotation of 360° in approximately 27 days.

As one observes the white light coronagrams, a slight difference in image quality can be noticed between images taken on different days. This is due to data compression, later referred to as corridor. Without data compression the entire 65,536 data points are read out on a scale of 1 to 128 brightness units and recorded onto the logic recorder. This requires 44 min readout time and limits the data to one picture per orbit. By using a corridor mode of data compression, the readout time is shortened, thus allowing more pictures per orbit and a closer look at a rapidly changing corona. However, there is a slight loss of intensity and spatial resolution in corridor mode.

There are three corridor modes available: ±3, ±6, and ±12 units of brightness. By preselecting a corridor, the number of data points required to construct a picture may be reduced. This reduction of data points is accomplished by writing out onto the tape recorder the value of the intensity point only if it differs from the previous value by more than the preselected corridor; otherwise it is skipped.

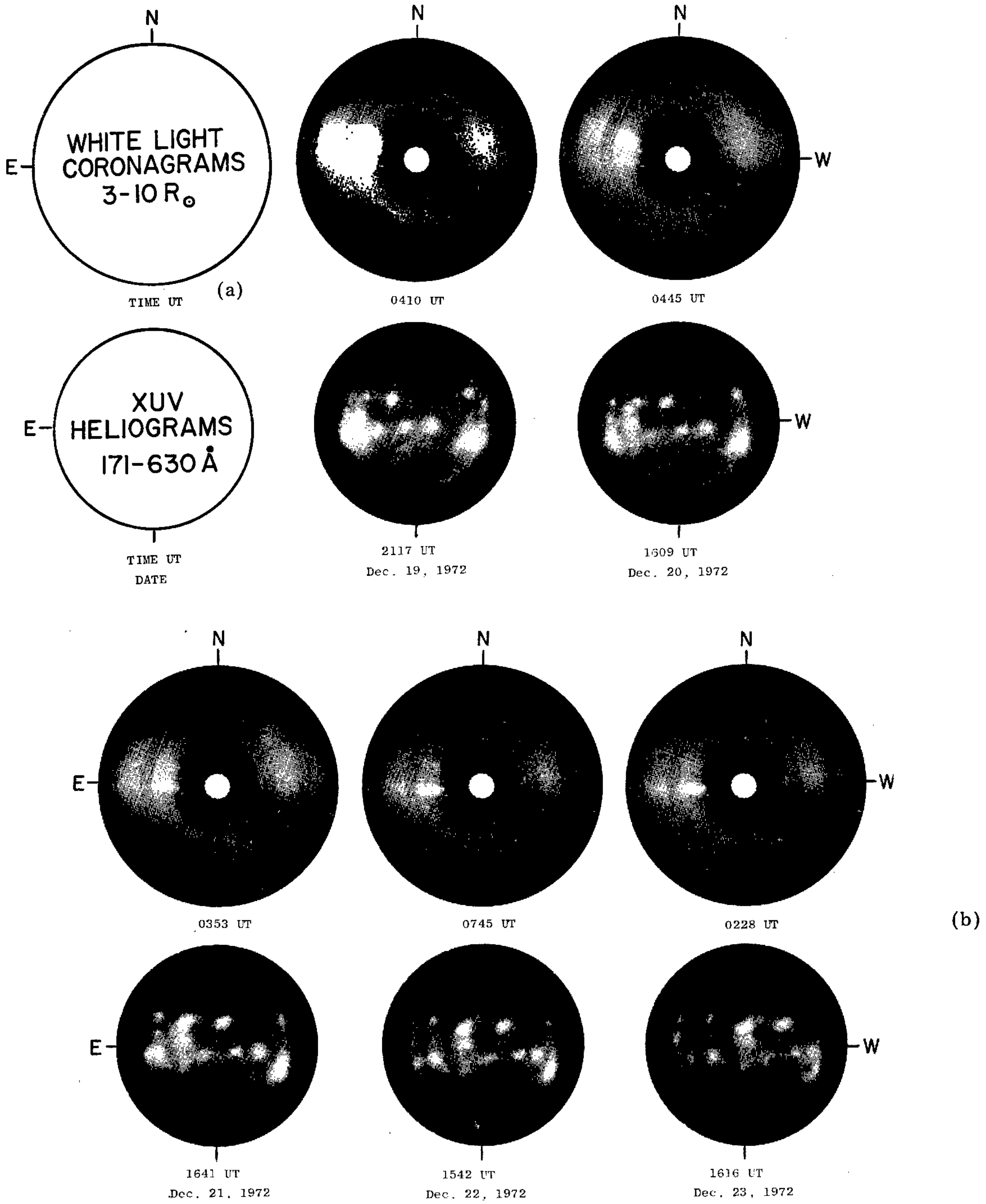


Fig. 6 — The top images are daily white light coronagrams recorded from 3 to 10 solar radii during one solar rotation. The bottom row of daily images was recorded in xuv light of wavelength 17 to 63 nm during one solar rotation. These images show the solar surface and patches of corona which lie above active regions.

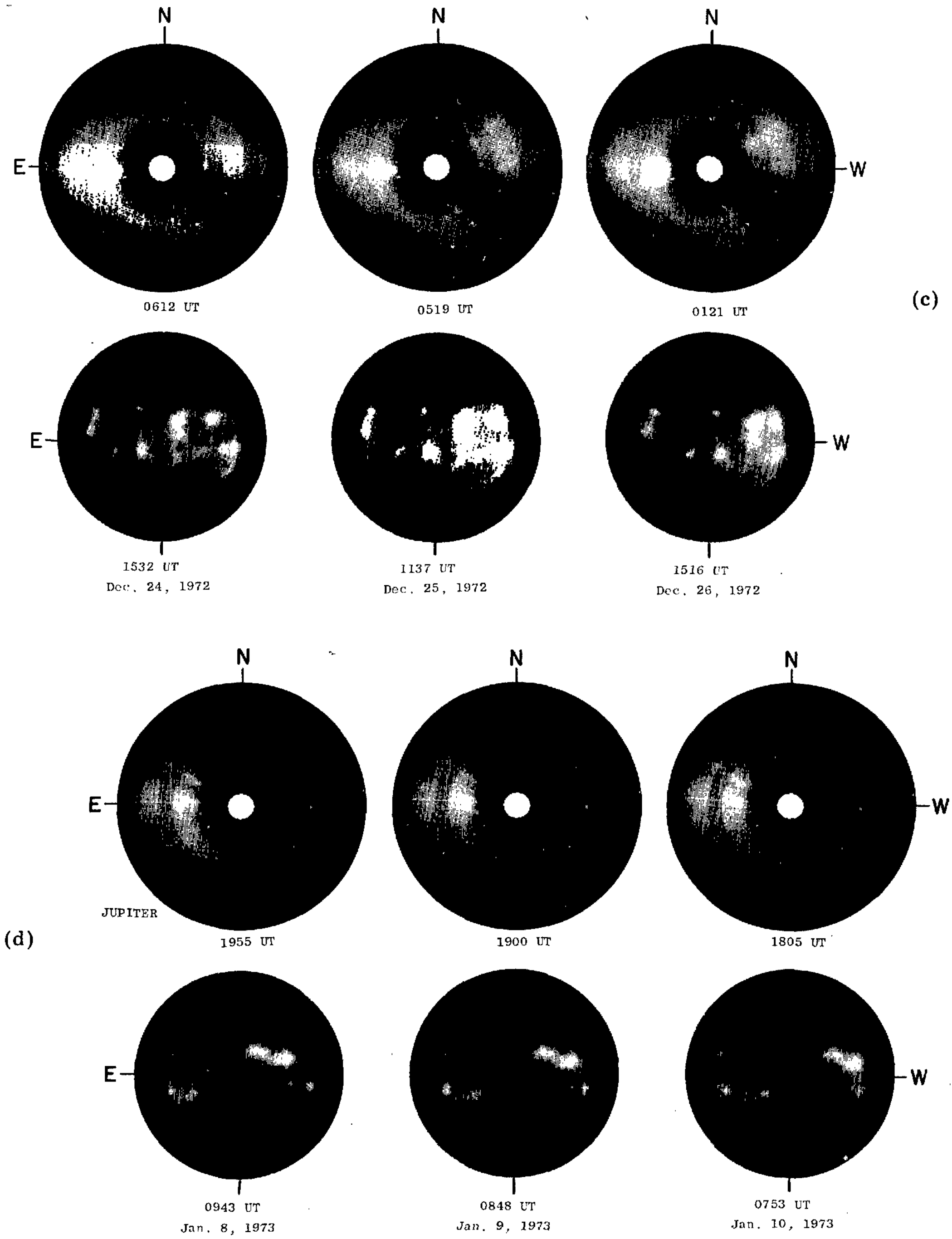


Fig. 6 (continued) — The top images are daily white light coronagrams recorded from 3 to 10 solar radii during one solar rotation. The bottom row of daily images was recorded in xuv light of wavelength 17 to 63 nm during one solar rotation. These images show the solar surface and patches of corona which lie above active regions.

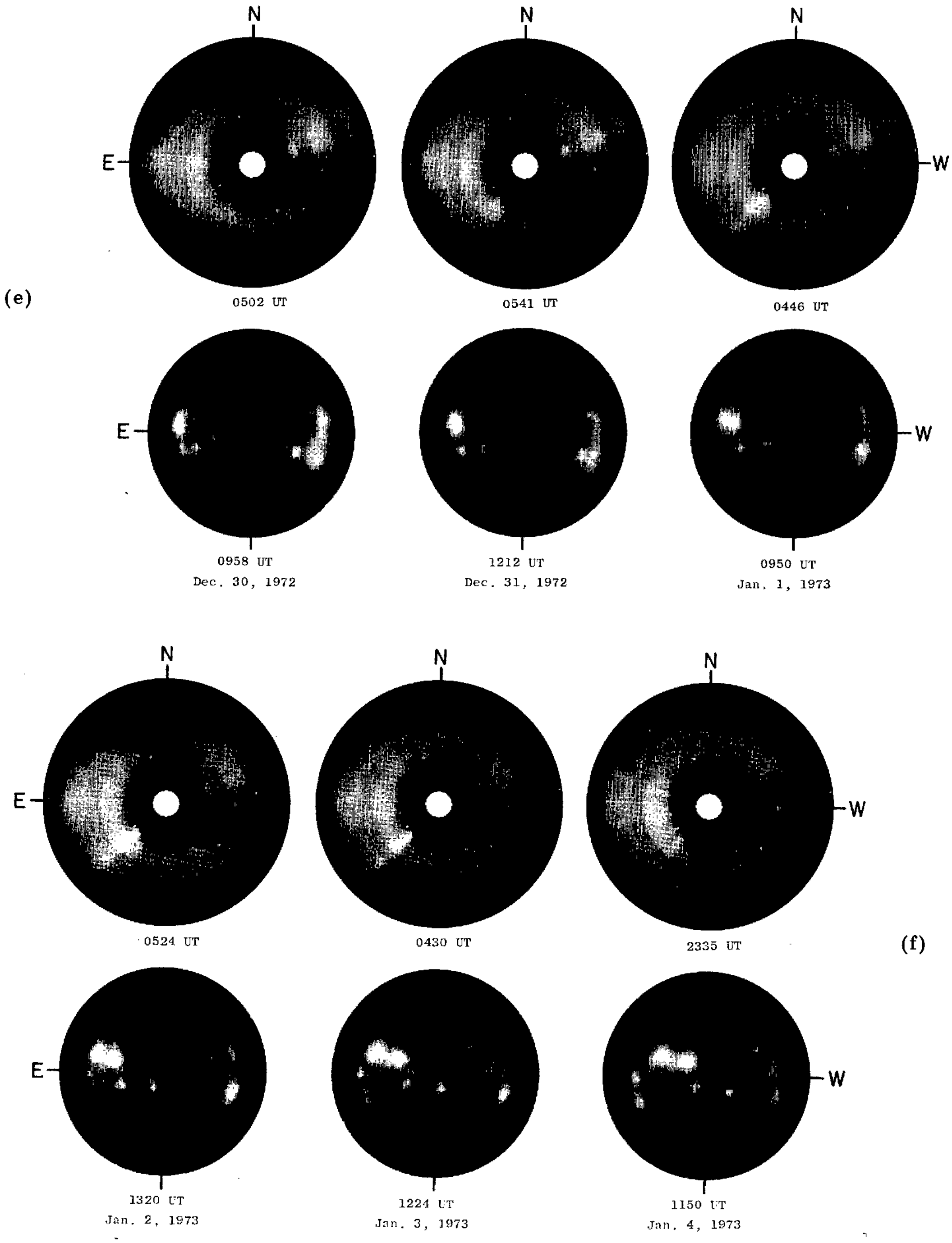
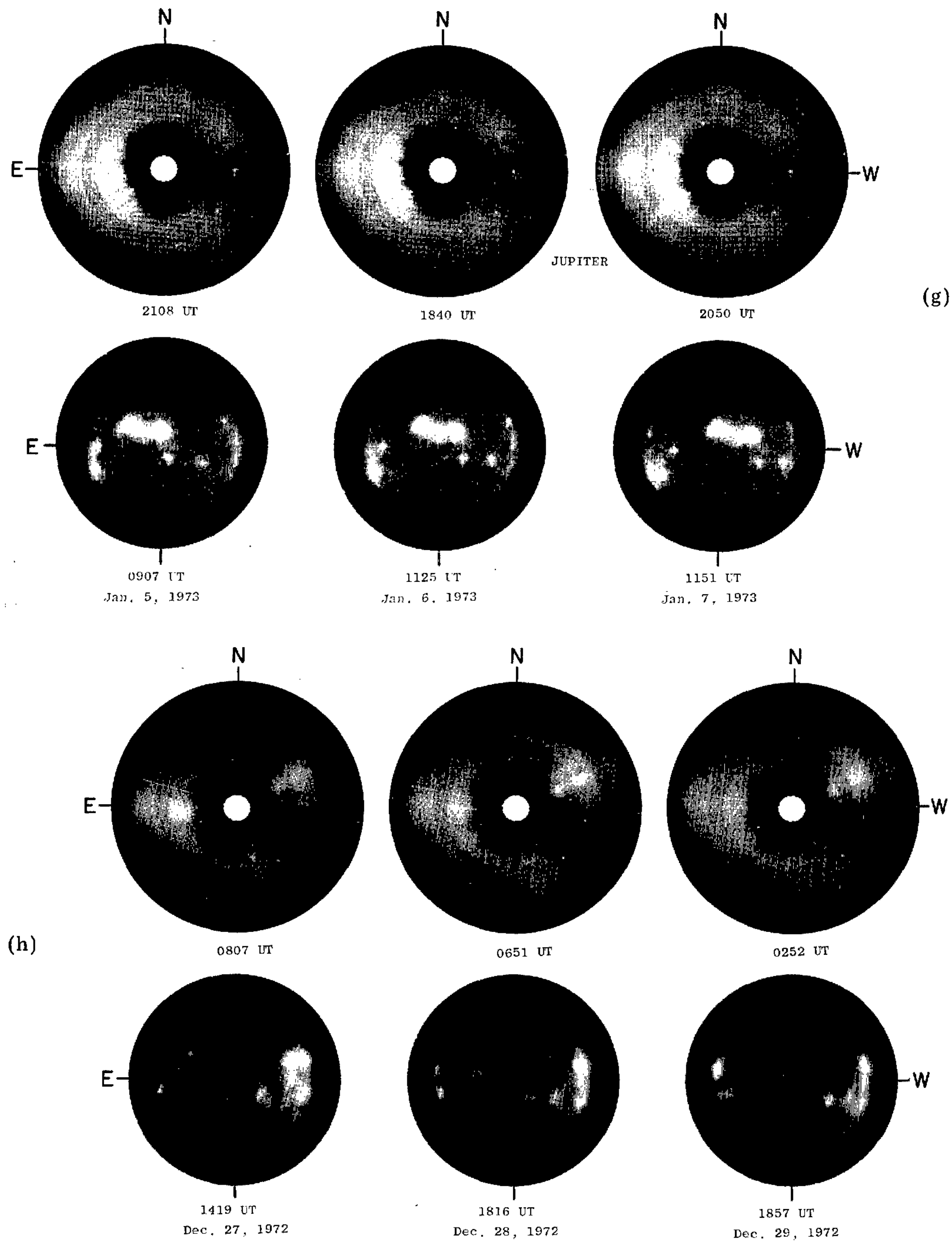


Fig. 6 (continued) — The top images are daily white light coronagrams recorded from 3 to 10 solar radii during one solar rotation. The bottom row of daily images was recorded in xuv light of wavelength 17 to 63 nm during one solar rotation. These images show the solar surface and patches of corona which lie above active regions.



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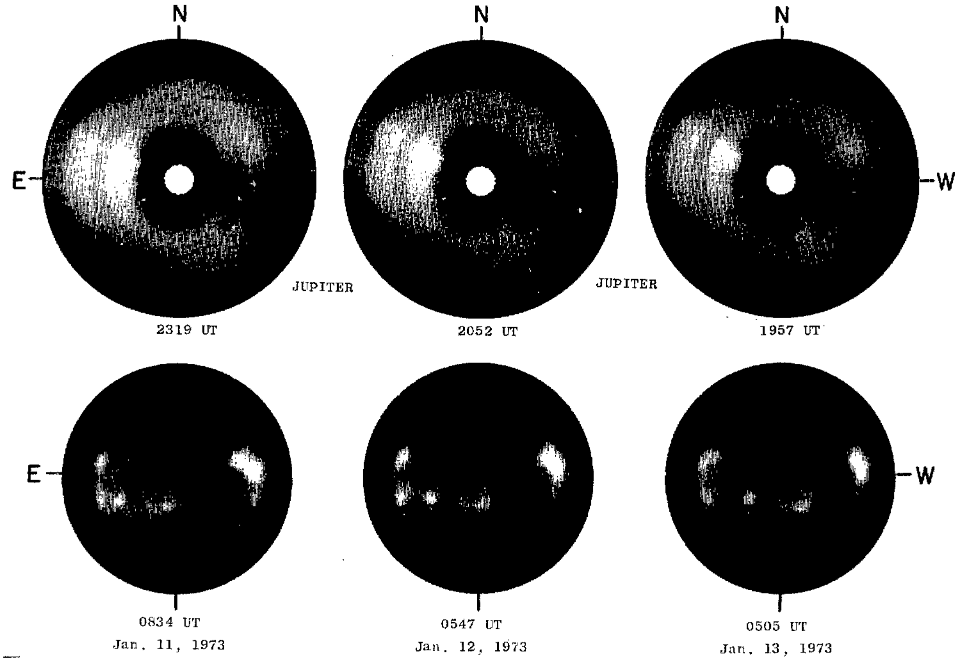

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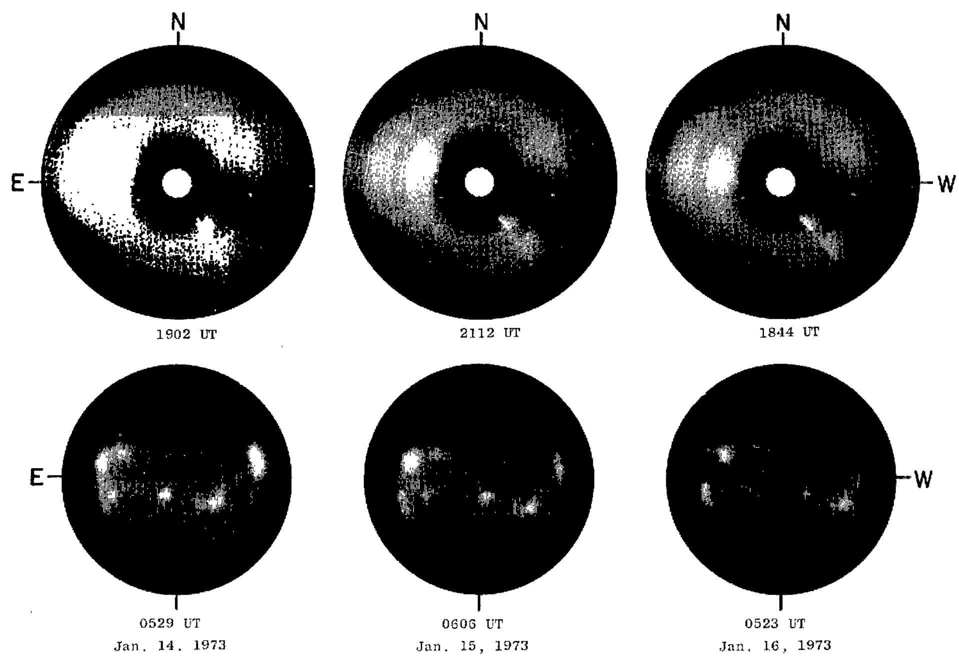

(j)

Fig. 6 (continued) — The top images are daily white light coronagrams recorded from 3 to 10 solar radii during one solar rotation. The bottom row of daily images was recorded in xuv light of wavelength 17 to 63 nm during one solar rotation. These images show the solar surface and patches of corona which lie above active regions.

The December 21, 1972 image was taken in 0 corridor (no data compression) and required 44 min of readout time; the December 22, 1972 image was taken in 12 corridor with 9 min of readout time; the December 23, 1972 image was taken in 6 corridor with 24 min of readout time; and the January 2, 1973 image was taken in 3 corridor with 35 min readout time.

Of particular interest is the corona series from December 24, 1972, to December 29, 1972. The bright streamer seen in the east shows an expansion in width reaching a maximum on December 26 and completely dissipating itself by December 29. One can imagine this streamer actually exploding and dissipating into space. To realize the enormous size of this streamer, the December 24 picture shows the streamer extending to approximately 10 solar radii (4.32 million miles), or 1/20 of the distance to earth. The width of the streamer at 4 solar radii is equal to approximately 48 earth diameters. On December 26, the width of the streamer at 4 solar radii had increased to approximately 108 earth diameters. Many of these streamer eruptions or explosions have been recorded during the past 2 years by the coronagraph.

From January 7 through January 12, 1973, the planet Jupiter (—1.4 magnitude) passed through the coronagraph's field of view. It can be seen moving from east to west as it passes on the far side of the sun (superior conjunction). The image is lost on January 9 and 10 as the planet passes behind the occulted area of the picture but emerges again on January 11.

Still another capability of the coronagraph is to record a preselected area of the corona. This is accomplished by dividing the recorded image into four 90° sectors. (See Fig. 3). Each sector may be individually recorded as often as needed. Figure 7 shows an example of this mode of operations. On January 16, 1972, the moon, traveling from west to east, passed within 1° of the sun. To follow this passage, several pictures were taken in each sector. Sector 1 in the northwest was taken at 0403 UT, sector 2 in the southwest was taken at 0542 UT, sector 4 in the southeast consists of two pictures taken at 1038 and 1355 UT, and sector 3 in the northeast was taken at 1513 UT. The resulting picture is a computerized composite of these different exposures.

On December 14, 1971, a massive eruption from the sun was observed traveling through its outer corona. (See Fig. 8.) During the explosive event, clouds of hot gas, some 40 times the size of earth, blasted away from the solar surface at speeds up to 600 miles per second. These clouds are visible on the east side of the picture.

Returning to the xuv data, Fig. 9 shows a single xuv picture of the sun from OSO 7. Spatial resolution of the system is 1 by 1.25 arcmin and is determined by the mechanical raster of the OSO spacecraft. In this figure the picture element size is considerably smaller (about 19 by 19 arcsec) than the spatial resolution element. This effect (matrix expansion) is introduced during processing. Contrast enhancement has also been employed. Bright regions in the picture represent hot, dense regions of the solar atmosphere. Darker areas correspond to cooler, and sometimes less dense, regions. Note the extended dark region near the top center (solar north pole) of the solar disk. Large regions of depressed xuv emission such as this one constitute a new class of coronal features of great current interest known as "coronal holes." They are thought to represent regions of open magnetic field configuration and may be the source of high velocity solar wind streams sometimes observed in the vicinity of earth. The small black spot at bottom center is due to a transmission dropout in the telemetry data stream.

SUMMARY

This report has presented only a small fraction of the total data available. We now have on hand for the first time a 2-year daily coverage of the sun's outer corona, which had preciously been glimpsed only during eclipses. A 2-year continuous record of the sun's xuv corona is also on hand. From this massive collection of data it is hoped that solar scientists will develop a better understanding of the sun.

ACKNOWLEDGMENTS

The success of a major experiment carried in such a vehicle as OSO 7 depends on the efforts of many individuals. Among those who contributed to the NRL experiment are R. Tousey, M. J. Koomen, D. J. Michels, C. R. Detwiler, G. E. Brueckner, D. M. Packer, I.G. Packer, R. A. Howard, H. W. Cooper, J. K. Smith, R. K. Chaimson, W. H. Funk, E. Spiller, and J. P. MacCormack.

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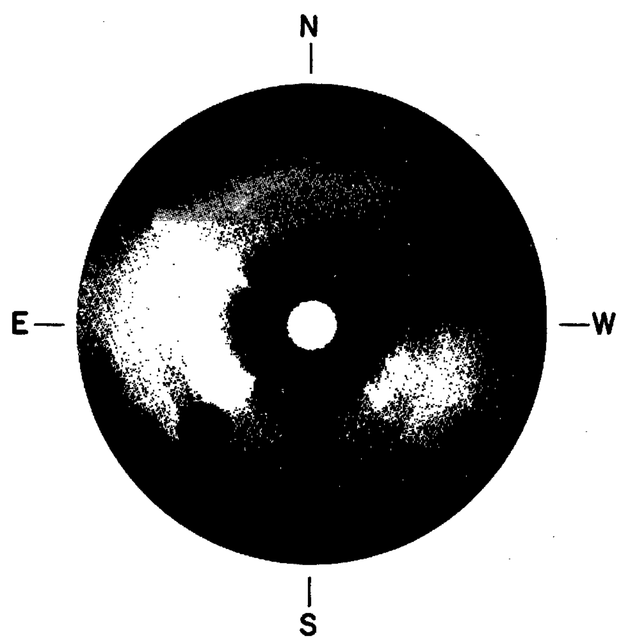

Fig. 7 — A multiple exposure in the white light coronagram showing the moon passing nearly in front of the sun. The moon is silhouetted against the corona, but some features of its surface can be seen by light reflected to it from the sunlit earth.

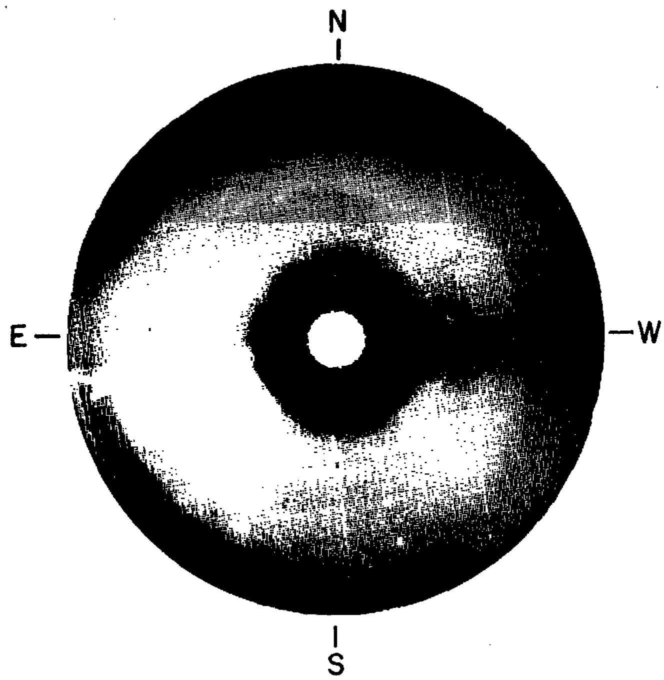

Fig. 8 — Clouds of hot gas being expelled to the southeast from the surface of the sun on December 14, 1971.

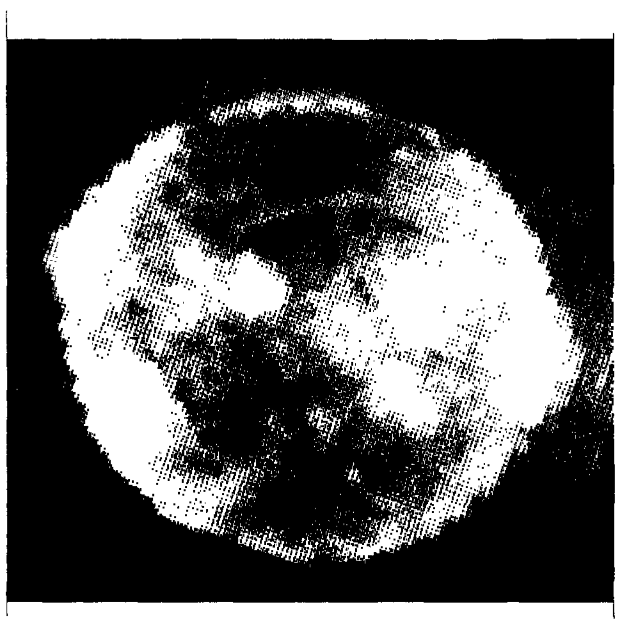

Fig. 9 — An xuv image of the sun showing bright patches of corona lying above many active regions