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THE MAKING OF THE FILM
SOLAR CORONA

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The film SOLAR CORONA was made from data taken from August 14, 1969 through May 7, 1970, by OSO-VI, one of the Orbiting Satellite Observatories. One of the experiments on board scanned across and up and down the image of the sun, as we read a printed page. Each line of the scan was broken up into several distinct measurement points, similar to our eyes fixating as we read a line of text.

Taking all the lines in one entire scan of the sun, these points make up a regular array, 64 points in one direction and 96 in the other. The data measured at each point is the intensity of light at that point in the sun's image. These measurements are already in the form of numbers (counts of photons detected by a photomultiplier). The numbers are radioed back to earth, where they are recorded on magnetic tape for analysis later.

Each time the satellite orbits the earth (once every 95 minutes), there is enough time to make several scans of the sun. Sometimes several scans would be made on one or more orbits and their data averaged to reduce the noisiness of the picture. On other orbits, only one or two, or even no scans, would be made, the time being used to run other experiments on board, or run this experiment in other modes.

The light which was measured in this particular experiment is actually light of only one color (wavelength 625 +or- 3 Angstroms). This "color" is actually in the ultraviolet beyond our range of vision. This particular wavelength was used because it is emitted by Mg X, magnesium with nine of its electrons removed. The high temperature needed to strip nine electrons off does not occur on the surface of the sun (5800 degrees), but only in the much hotter corona above the surface (about 2 million degrees).

Thus all the data originates not in or on the sun itself, but in the hot gas surrounding the sun. The density of this gas, however, is related to what the sun beneath it is doing. Since a higher density will produce more 625 Angstrom light, the measurements can tell us about features of the sun, such as active regions.

Active regions are areas where the normal structure of the surface of the sun is disturbed. Solar flares are eruptions lasting from a second to several hours, and occur in active regions, although the data from this experiment does not especially distinguish active regions with flares from those without flares. Sunspots, which occur in many active regions, have strong magnetic fields and a longer lifetime, and are a little cooler than normal sun urface. Because of its high density, gas above active regions emits more 625 Angstrom light and appears as a cluster of higher numbers in the scan of the sun.

Astronomers sometimes make computer print-outs of entire scan pictures of the sun. Colored marking pens can be used to color each data number, different colors for different ranges of numbers.

If we use white or pink for the largest numbers, then strong active regions show up as patches of white or pink. Using black for the lowest data makes the background beyond the sun's corona black. Other colors can be used for intermediate data numbers.

Coloring a print-out this way as soon as it is received from the satellite gives astronomers a quick idea of what features are developing on the sun. If it looks like a large active region is appearing, then measurements which are best for examining active regions might be made on the next orbit or series of orbits to get a full story on how the region develops. The magnetic tapes on which the data is recorded are often read into a computer, which is then used to process the data in various ways. The satellite does not always face the sun in the same orientation; sometimes it scans the sun upside down, or tilted to the right, or to the left. One of the uses of the computer is to rotate the scan pictures so north is always at the top.

Another is to correct each picture for overall changes in the sensitivity of the light sensor. If the sensor happens to be more sensitive during a particular scan, for example, then the data will erroneously imply that the sun suddenly got brighter then.

Yet another application of computer processing is to interpolate new data points between those which were actually measured. Thus the 64 by 96 array can be converted, for instance, into one 96 by 96. All three of these computer applications were used in making this film. They were done on a CDC 6400 at the Harvard College Observatory, whose programmers then prepared a second magnetic tape of the results.

This new computer tape was then brought to the AI Lab at MIT, where a fairly simple program was used to actually photograph the images. Each of the pictures (a total of 230) was read into a PDP-6/PDP-10 computer. After each picture was read in, it was displayed on a color (21FJP22A color TV tube) computer display. It was displayed as an array of 96 by 96 points. Each point was displayed with the color assigned to the range in which that point's data number fell. This can be thought of as a computerized paint-by-number picture, like using colored pens as described above. A movie camera loaded with color film (Ektachrome EF) was focused on the display. The only filters used were color correction filters to balance the display's colors to the film's sensitivity. The computer had control of the camera's shutter and film advance.

Along with the arrays of data numbers, the computer tape had the date and time at which each picture was taken. Thus a caption showing this was displayed for each picture. Furthermore, the computer used the amount of time elapsed between pictures to calculate how many movie frames each picture should appear on to achieve accurate time scaling.

The computer opens the shutter, displays the picture and caption, closes the shutter and advances the film. This sequence is repeated until the number of frames appropriate to the current picture are exposed. Then the next picture is read into the computer and treated similarly.

The filming program also fades from one picture to another. When it's time for a new picture, the old and new pictures are averaged together for a few frames. The weighting of the old one is steadily decreased, while that of the new one is increased. This gradual fading helps alleviate jumpiness when the picture changes.

Watch for these features as you view the film:

(1) The first sequence, at 1 second = 12 days, is to give a feeling of the sun as a rotating, 3-dimensional object. It revolves once every 27 days, although this is a rough figure since different latitudes and features rotate at different rates.

(2) The regions of the sun emitting the most light are white; next dimmer are pink, red, orange, etc. Blue, purple and finally black are dimmest. This "rainbow" color assignment provides a better impression of continuity than other assignments which were tried. Notice the active regions as shown by red, pink and white.

(3) This film includes data taken on the date of the solar eclipse of March 7, 1970. While looking at other solar data taken during the eclipse, astronomers noticed a large "hole" in the corona. This "coronal hole" is obvious in the film. Watch the bottom half as it comes into view about February 22 at the lower left and crosses the screen to the right. The hole, perhaps a million degrees cooler than normal sun surface, is a large region with lots of black and a purple border. Some remnants of it seem to remain on the next rotation, a whole month later. And perhaps there are hints of it in earlier months. It is thought that low solar magnetic fields in such "holes" may allow numerous particles to stream away from the sun, making a large contribution to the "solar wind."

(4) The satellite's orientation was not quite accurately corrected on the February 3 picture, making it look like the sun twists clockwise on February 3, and then back on the next picture.

(5) Two effects cause deterioration of the pictures. First, some pictures are not an average of several scans, but are only one or two scans. For these, the noisiness inherent in the measurements shows up much more. Second, the light sensor (photocathode) slowly deteriorated during the experiment. The first several pictures re very noise-free and solid looking. The last-but-two two (May 2 and 4) are particularly blotchy due to both these effects. Some intermediate pictures suffering from various amounts of noise occur on November 15 (second picture) and 17, December 10, and March 17.

(6) The computer correction for variation in sensitivity of the light sensor was not always quite right. Sometimes the sensitivity is higher than allowed for, giving the picture a more yellow and orange cast (such as December 7); at other times the sensitivity is lower, resulting in more greens and blues (February 16).

A PDP-6 version of a 10-year old PDP-1 music playing program by Peter Samson produced the sound track. It can sound a square wave on any of 6 independent voices. Musical scores used by permission. Thanks to David Cohen for help with the musical score, and to the MIT film section for help with production.

The credits scene reads:

Mg X intensity from OSO-VI
August 1969 - May 1970

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Solar Satellite Project	Dr. Edmond Reeves
Mg X experiment	Dr. George Withbroe
astronomy data programmers	Judy Smith and Pat Thomas
cinematography	Michael Beeler

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references:
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Harold Zirin, The Solar Atmosphere, Blaisdell Pub. Co. 1966
"Science News," January 27, 1973, vol. 103 no. 4 p. 60

The film is 16 mm, 6 and 1/4 minutes, color, optical sound.