SOLAR OBSERVATIONS WITH A NEW EARTH-ORBITING CORONAGRAPH

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Abstract: Since March 28, 1979, the Solwind coronagraph has been observing the Sun's white light corona (2.6 - 10.0 $R_\odot$) routinely with a spatial resolution of approximately 1.25 arc min and a repetition rate of 10 minutes during the one-hour sunlit portion of each 97-minute satellite orbital period. These are the first satellite observations of the outer corona near the peak of a sunspot cycle when coronal transients and high-latitude streamers are common.

Satellite observations of the Sun's white light corona began on October 4, 1971 when the Naval Research Laboratory's coronagraph on OSO-7 started its 2.7-year interval of operation (Howard et al., 1975; Koomen et al., 1975). The High Altitude Observatory continued coronal observations during May 1973-February 1974 with its coronagraph on the Skylab Apollo Telescope Mount (MacQueen et al.,1974). This paper presents a sample of observations obtained with a new NRL coronagraph called Solwind that is currently operating on the U. S. Department of Defense Space Test Program Satellite P78-1 in a noon-midnight polar orbit.

In Figure 1, coronal images obtained with the OSO-7, Skylab, and Solwind instruments are compared at the same spatial scale. A small white area and an NRL He II 304 Å spectroheliogram have been placed in the centers of the OSO-7 image (left) and the Skylab image (center), respectively, to indicate the size of the solar disk. The OSO-7 and Solwind images have similar fields of view ranging from the edges of their occulting disks at approximately 2.6 $R_\odot$ to their outer limits of 10.0 $R_\odot$. The Skylab image shows a corresponding field of view from 1.5 $R_\odot$ to 6.0 $R_\odot$. However, the OSO-7 and Solwind images have a spatial resolution of only 1.25 arc min, whereas the Skylab image has a resolution of 8 arc sec (MacQueen et al., 1974). Perhaps the greatest advantage of the Solwind instrument over its predecessors is its relatively larger duty cycle which is limited only by the periodic passage of the satellite into the Earth's shadow for approximately 30-minute intervals.

Figure 1 also illustrates the changing character of the outer corona during the sunspot cycle (cf. Van de Hulst, 1953). The OSO-7 and Skylab

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images were obtained during the declining phase of the previous cycle, and show streamers that are confined primarily to low latitudes. The Solwind image was obtained during the present approach to sunspot maximum, and shows streamers in more-or-less all directions. In particular a narrow, bright streamer is visible 15° east of north and a faint one is visible 10° west of north. Such high-latitude streamers were not observed during the OSO-7 and Skylab missions.

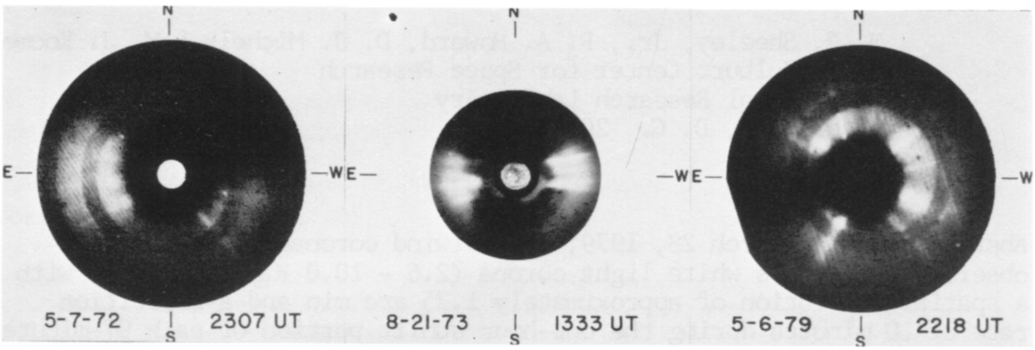

Fig. 1: OSO-7 (left), Skylab (center), and Solwind (right) coronal images illustrating the fields of view, spatial resolutions, and coronal conditions obtained with each instrument. The size of the solar disk is indicated by the white area and He II 304 Å image in the centers of the OSO-7 and Skylab images, respectively.

Figure 2 shows a sample of Solwind coronal images during May 6-9, 1979. Here, the outer limit of the field of view has been masked down to approximately 8.4 $R_\odot$. The narrow streamer 15° east of north seems to persist (with some changes) from May 6 to May 9. This suggests that the intervening frames will show the evolution of such high-latitude streamers relatively free from the effects of overlap and solar rotation that hindered previous studies of low-latitude streamers.

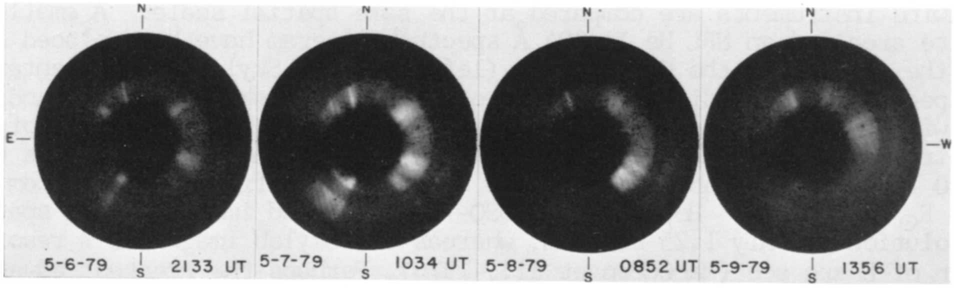

Fig. 2: A sample of Solwind coronal images during May 6-9, 1979 illustrating the daily changes in the pattern of coronal streamers.

Figure 2 also shows some major coronal changes from day to day. A structure in the southeast is relatively bright at 1034 UT on May 7, but

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hardly visible at 0852 UT on May 8. A similar change occurred in the southwest between May 8 and May 9. Subtle, but definite, changes also are visible in the northeast during May 6-7 and northwest during May 7-8. Intervening images show that all of these changes were associated with coronal transients. The May 7-8 transients are shown in the next figure, and the May 8 transient is described elsewhere (Michels et al. 1979a, b).

Figure 3 shows four "difference" images formed by subtracting pairs of images obtained at the indicated times. In the southeast the 8.4 $R_\odot$ mask has been cut to show the structure out to 10.0 $R_\odot$. In the northwest, a mass ejection is clearly visible during the interval 1805-2214 UT on May 7. Unlike the "loop" transients which were so common during Skylab and which we observed in the southwest on May 8, this transient does not show a well-defined, continuous, curved, advancing front. Instead, this transient consists of several outward-extending, spiky structures. Also during this event the isolated streamer 15° east of north seems to have moved or been pushed slightly away from the transient.

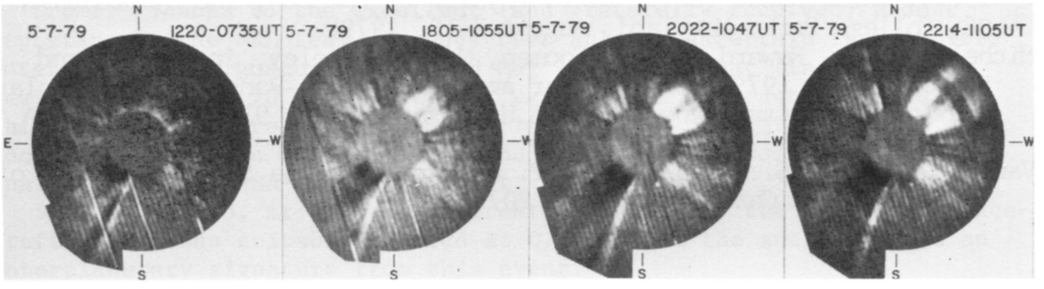

Fig. 3: "Difference" images formed by subtracting pairs of images at the specified times. The dark pattern in the southeast and the bright pattern in the northwest indicate coronal mass ejections that were in progress during the first and second halves of May 7, respectively.

Figure 3 also shows evidence for the outward expansion of a looplike transient in the southeast quadrant during the interval 0735-1220 UT. The "1220-0735" difference image shows a dark loop near 3 $R_\odot$ and a faint bright structure near 7 $R_\odot$ as if the transient had expanded outward during this interval. In the "1805-1055" difference image the entire pattern is dark, indicating that the transient faded by 1805 UT. Near the southward boundary of this transient, a very long streamer seems to have been displaced and bent southward. Such transient-induced streamer displacements were observed during the Skylab mission (Hildner et al., 1975) ,but are shown much more dramatically in these Solwind difference images.

This effort to orbit a small coronagraph capable of nearly continuous solar monitoring has received substantial assistance from several sources. The NASA Office of Solar Physics provided spare coronagraph and solar pointing flight hardware from its OSO-7 program, and also supplied ground station support that has allowed quick access to the Solwind data. The Department of Defense Space Test Program provided integration and launch support and the Office of Naval Research provided financial support. At NRL, F. Harlow, D. Roberts, R. Chaimson, and R. Seal provided the technical and engineering support that helped to make this project a success.

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DISCUSSION

Webb: Have you developed sufficient statistics to be able to confirm the predictions of the Skylab/HAO group of the increased frequency of transients during solar maximum?

Sheeley: No. We have been observing routinely since March 28, 1979, but we have received less than 10% of these data so far.

Kahler: Can you compare the instrumental sensitivities of the P78-1 coronograph with those on Skylab and the OSO-7?

Sheeley: I have not made this comparison, but my co-authors say that the sensitivities of the Solwind and OSO-7 instruments are comparable, but that the Solwind instrument has a lower noise level than the OSO-7 instrument. Eventually we will probably compare the sensitivities of these coronographs with that of the Skylab coronograph and the planned SMM coronograph.

Bhonsle: (1) It is possible to delineate the time evolution of coronal transient from your observations? If so, with what time resolution? (2) What is the frequency of occurrence and average life-time of a coronal transient?

Sheeley: (1) Yes. On Thursday Donald Michels will describe the detailed solution of the May 8, 1979 transient with 10-minute temporal resolution during the 60-minute sunlit portions of 2 or 3 consecutive 96 minute satellite orbital periods.

(2) We have not yet seen enough of our data to determine the frequency of occurrence of transients at this phase of the sunspot cycle. However, during the interval May 6-9, 1979 we have seen a significant part of our data and in this case we observed at least 4 transients. At a propagation speed of 500 km/sec, it takes about 3 hours for a transient to cross our field of view from 2.6 $R_\odot$ to 10.0 $R_\odot$. The remaining time for the coronal intensity to fade varies from event to event.

Bird: The coronograph images seem to exhibit a decrease in intensity at all position angles about halfway out in the field of view. Is this an instrumental effect?

Sheeley: Yes. Our instrument contains two eccentric, but nearly circular, analyzers for the linear polarization that is expected for Thomson-scattered radiation from electrons in the plane of the sky.

Dryer: Thanks to the excellent (and gratefully received) prompt reporting by the NRL team, we have been able to ascertain the possible interplanetary signature of your 8 May 1979 transient (in the Southwest) at Venus (0.78 AU, about 110^o west of the sun-earth line on this date). The preliminary identification was possible with the cooperation of John Wolfe, PI for the Pioneer-Venus solar wind plasma analyzer of the NASA-Ames instrument.

Sheeley: Also, it will be interesting to see if the Helios II spacecraft (which was suitably located at 0.3 AU from the sun) detected an interplanetary signature from this event.

Jackson: When will you have a list of transients from your instrument?

Sheeley: We have a small list now and are adding to it day by day as we receive and look at our data.