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Scientific Results of the First Orbiting Solar Observatory

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The first Orbiting Solar Observatory (OSO 1) was launched March 7, 1962, into a nearly circular 575-km orbit of inclination 33°. This was the first satellite designed to point instruments actively at the Sun. For the frst three months the satellite performance was nearly perfect. Since that time the loss of the tape recorders, the decrease of available power, and other problems have degraded the spacecraft performance. However, data varying in quality from continuous to intermittent have been obtained during the periods from March 7 to May 23, 1962; June 23 to July 7, 1962; and October 14, 1962, to date. The pointing accuracy during these periods has consistently been within ±2.5 arc minutes in elevation and ±1.0 arc minute in azimuth with respect to the center of the solar disk.

The tremendous quantity of data collected continues to be reduced and interpreted. Available results were presented by the several investigators at the spring Annual Meeting of the American Geophysical Union.

W. E. Behring and W. M. Neupert of Goddard Space Flight Center reported on measurements of the solar spectrum from 50 to 400

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angstroms utilizing a scanning monochromator as a pointed experiment on OSO 1. In the 50–400 A spectral range the radiation appears as an emission line spectrum produced by highly ionized coronal ions. The period of observation was sufficient to observe variations in the solar flux correlating with solar activity.

Data showed an increase in the He II Lyman-alpha (304 A) flux, integrated over the entire solar disk, of 33 per cent during a period when the Zurich Provisional Relative Sunspot Number increased from zero (March 11, 1962) to a maximum of 94 (March 22, 1962). Enhancements of shorter duration, not always associated with chromospheric flares, were also observed. In one case the increase in the helium line was 14 per cent during a flare of importance 3, which occurred on March 22, 1962.

The coronal lines produced by iron show a more pronounced change. Both Fe XV 284 A and Fe XVI 335 A increased by approximately a factor of 4 during the period March 11 to March 22, 1962.

W. A. White, R. M. Young, and J. C. Lindsay of Goddard Space Flight Center discussed the 1–10 A solar X-ray emission observed from OSO 1. Experimental emphasis was on providing data on the quiet Sun. Data from the extremely quiet period March 8, 1962, to March 11, 1962 (Zurich provisional relative sunspot number was zero for the 11th of March), established a quasi-stable background X-ray flux with occasional bursts superimposed. The quiet Sun flux for the period was 3×10^{-4} erg/cm^2-sec for the wavelength interval from 1 to 10 A. A theoretical background based on a 1.8 million degree corona falls short of the measured flux by a factor of 360. Thus, the process responsible for the quasi-stable background solar X-ray flux during times denoted as 'quiet' is probably already a nonthermal one, and the additional X-ray flux during bursts represents an even greater departure from thermal processes.

Evidence of a regular pattern in both times of occurrence and intensities of X-ray bursts (or microflares) was found; the pattern takes the form of a geometrical progression. Both decreasing and increasing progressions were found, all with identical parameters except for a slope of reversed sign. Analysis of the data is continuing in an effort to understand the observations and develop a model explaining the phenomenon.

Kenneth Hallam and Robert Young of Goddard Space Flight Center gave an account of solar Lyman-alpha flux monitoring from OSO 1. The detector used was a CS$_2$-filled ion chamber with a LiF window.

The recorded average solar flux in the spectral region 1050 to 1230 A was 4.9 ± 0.1 ergs/cm^2-sec for the first 40 orbits. Lyman alpha contributes about 95 per cent of the flux in this bandpass. The remainder is mainly due to Si 3, λ 1206.5 A. After the first 230 orbits, the ion chamber sensitivity declined at a rate of about 20 per cent per week. This, however, had no effect on short-term relative measurements.

A flare of importance 2+ on March 13 caused a peak enhancement in Lyman alpha of 5.3 per cent. An increase of 6.8 per cent was observed during an importance 3 flare on March 22. This represents a local brightening in Lyman alpha of between 5 and 150 times, depending on the background situation.

K. J. Frost, E. D. Rothe, K. Hallam, W. A. White, and H. M. Horstman of Goddard Space Flight Center discussed two experiments designed to search for solar gamma radiation in the region 20 kev–1 Mev. The first experiment consisted of a thin NaI(Tl) crystal (2.22-cm diameter × 0.15-cm height) scintillation counter surrounded by a copper shield. The objective of this experiment was to search for solar bremsstrahlung bursts in the 20- to 100-kev range. The second experiment employed three scintillation counter detectors. Two NaI(Tl) (3.8-cm diameter × 3.8-cm height) crystals were placed in the wheel section of the Observatory and one (3.8-cm diameter × 5.08-cm height) CsI(Tl) crystal was placed in the pointed section. These crystals measured the spectrum of gamma rays between 0.100 and 1.00 Mev with particular emphasis on the 0.511-Mev positron-electron annihilation line and its temporal variation. The object here was to search for positron-electron annihilation radiation of solar origin.

The results of the 20– to 100-kev experiment indicate that the flux from the quiet Sun cannot be in excess of 3.40 ± 0.95 photons/cm^2-sec in this energy range. At the time of the report no solar bremsstrahlung burst had been detected. This data survey includes most of the information acquired during March and April of 1962. It is pertinent to note that no solar proton events occurred during this period. The counting rate in the 0.1- to 1-Mev range was found to be 4.7 ± 0.5 counts/cm^2-sec. The data also indicate that the upper limit of the positron-electron annihilation radiation flux from the Sun is 0.6 ± 0.2 photon/cm^{2}sec.

Laurence E. Peterson of the University of California, La Jolla, discussed efforts to measure gamma rays from OSO 1. His experiment was designed to search for extraterrestrial gamma rays in the 50-kev to 3-Mev energy range. The apparatus consisted of a 2.5-cm diameter × 1.25-cm-height NaI counter with a 0.5-cm lead collimating shield for 50- to 150-kev photons. A Compton telescope, consisting of a 3.2 × 3.2-cm NaI counter in coincidence with a phoswich-type NaI counter (5.1-cm diameter × 5.7-cm height) provided a directional detector for gamma rays between 0.3 and 3.0 Mev. The counting rate of the low-energy telescope near 0° geomagnetic latitude is 1.0 ± 0.1 count/cm^2-sec, most of which is local cosmic-ray-produced background. The solar flux at the Earth is less than 1 photon/cm^2-sec or 1.6 × 10^{-7} erg/cm^2-sec between 50 and 150 kev. No increases were noted during the flares on March 11 and March 22, 1962, and no significant variations above background over the celestial sphere have been observed. Typical total rates measured by the phoswich NaI counter at 0° geomagnetic latitude are 0.40 and 0.18 count/cm^2-sec for photons with energy losses of 0.3–1.0 and 1.0–3.0 Mev, and 0.35 count/cm^2-sec for particles losing more than 1 Mev. The respective rates at 40° geomagnetic latitude are 0.64, 0.44, and 1.6 counts/cm^2-sec. Most of the gamma rays in this energy region, immediately above the Earth's surface, are either Earth albedo or of local origin.

Carlton D. Schrader, Aerospace Corporation, and R. C. Kaifer, J. A. Waggoner, J. H. Zenger, and S. D. Bloom of the Lawrence Radiation Laboratory, University of California, reported on results obtained from their proton-electron experiment. The object was to determine the time and position variations of the fluxes of protons of energies greater than 1.5 Mev and electrons of energies greater than 110 kev near the lower boundary of the inner Van Allen belt. The detector used was unique in space flight and utilized the principle that in certain scintillators protons and electrons produce fluorescent pulses of distinctly different decay times. This made it possible, through electronic pulse shape discrimination, to employ a single crystal on a single photomultiplier to detect and count separately both protons and electrons.

One of the most interesting preliminary results was the discovery of a number of 'warm spots' (as contrasted to the anomalous South Atlantic 'hot spot'), where the electron flux is more intense than the average intensity by factors up to 50. These warm spots are apparently constant in time, intensity, and position. They are all located between latitudes 33°N and 33°S (the limiting orbital latitudes of the satellite) and occur over Madagascar, western Australia, eastern Australia, northwest of Hawaii, off Lower California, and in the South Pacific. Preliminary analysis has included the plotting of the warm spot intensities as a function of the natural trapped-particle coordinates, *B* and *L*. The warm spot intensity plots form well-defined curves in *B–L* space, which differ, however, from curves for similar *B* and *L* plotted from data recorded over other geographical locations. Thus, instead of a previously supposed longitudinal invariance, these data seem to indicate that at this altitude (near 575 km) there is a definite dependence on longitude. The authors stated that they are attempting, in a preliminary theoretical interpretation, to explain the warm spots as being due to trapped radiation, which is supplied at equilibrium rates from the lower Van Allen zone. As these low-altitude trapped electrons drift eastward across the Americas and the Atlantic they are lost because the South Atlantic anomaly causes them to mirror below sea level. This accounts for the low intensities for a given *B* and *L* in this region. Even though most of the electrons have been wiped out recently in their passage across the Atlantic, warm spots are already re-established east of Africa. This is regarded as evidence that the warm spots are being constantly supplied from higher altitudes.

The general proton data exhibited less structure, but an apparent small monotonic increase of proton intensity as a function of time is being investigated. To check this point further it is planned to continue to record additional data (still available from the satellite on a real time basis). Only one very-low-intensity proton warm spot has been observed so far, and this is above the Indian Ocean between Africa and Australia.

Also of considerable interest were the many narrow but intense peaks of both protons and electrons, which frequently occurred superimposed on the 'normal' structure and were presumed to be due to precipitation of previously trapped particles by magnetic disturbances. Many such intense peaks were found, e.g. in the data of March 12, 13, and 14, 1962, a period of unusual solar activity. The artificial radiation belt formed by the Starfish high-altitude nuclear test (July 9, 1962) was also observed over a limited area, and the subsequent time history was recorded.

As expected, both electron and proton fluxes were very high (so as to saturate the detector) over the South Atlantic anomaly. An effort is being made to determine the proton fluxes in this region through correlation of the proton information with the neutron data of W. N. Hess whose instrument is also on OSO 1. His detector was designed to determine neutron fluxes outside the anomaly, but in the anomaly it acts as a low-efficiency proton detector through the (*p*,*n*) reaction. All of these preliminary results have been obtained from analysis of just a small fraction of the total mass of data recorded by OSO 1, and final results should give a much more complete picture.

G. G. Fazio of the University of Rochester and Smithsonian Astrophysical Observatory reported on his attempt to detect high-energy solar gamma rays. The high-energy gamma-ray detector aboard the OSO 1 was designed to provide the first view of a solar flare in the >100-Mev region of the electromagnetic spectrum. A partial analysis of the data has shown no evidence for this radiation from the Sun, even during the importance 3 flare of March 22, 1962, and the importance 2+ flare of March 13, 1962. The upper limit of the flux from each of these flares was estimated to be 10^{-2} photon/cm^2-sec, and that for the quiet Sun, 7×10^{-3} photon/cm^2-sec. The flux from the total sky was less than 6×10^{-3} photon/cm^2-sec ster. Locally produced background radiation limited the sensitivity of the detectors. A more complete understanding of this background radiation will permit a sensitivity of 10^{-8} photon/cm^2–sec from the Sun.

W. N. Hess of Goddard Space Flight Center discussed his experiment for the detection of solar neutrons. A $B^{10}F$ proportional counter was flown on OSO, and an attempt was made to observe diurnal variations of its counting rate, as well as the Haymes sunset effect. Combining data from 42 orbits gave essentially no presunset maximum to within 10 per cent. However, there does appear to be a variation of the neutron count rate from day to night. The ratio of count rates/day to rates/night is 1.08 ± 0.01. It is currently uncertain whether there is a concurrent proton excess associated with this daytime neutron excess.