Measurements Made of High-Energy X rays Accompanying Three Class 2+ Solar Flares

T. A. CHUBB, H. FRIEDMAN, AND R. W. KREPLIN

U. S. Naval Research Laboratory
Washington 25, D. C.

During the summer of 1959 rocket measurements were made of high-energy X rays accompanying three class 2^+ solar flares. The rocket measurements began August 24, 1959, at 22:47 UT, August 31, 1959, at 22:53 UT, and September 1, 1959, at 17:00 UT. Four measurements were also made during times in which no flare activity occurred on the sun, but which were typical of sunspot maximum conditions. The data from these flights have been only partly analyzed, but many of the main conclusions can be drawn from these preliminary results. Further corrections will be made when the data have been completely analyzed. Such corrections, however, are not expected to affect the principal conclusions materially.

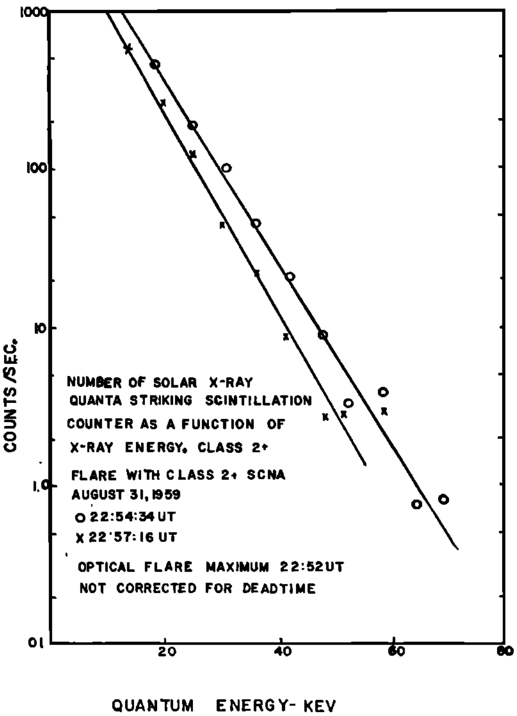

Fig. 1. Number of solar X-ray quanta striking scintillation counter as a function of quantum energy at two times during August 31, 1959, flare.

The most interesting results concern the detection of a considerable flux of solar X rays of energy greater than 20 kev during each of the three class 2^+ flares. Each flare was accompanied by an SID. In the two stronger flares solar X rays were first observed at altitudes below 43 km. Figure 1 shows a plot of number of X-ray quanta as a function of energy, measured during the medium-intensity class 2^+ flare of August 31, 1959. The X-ray distributions were determined from pulses produced in a scintillation spectrometer. The X-ray flux persisted throughout the 6 minutes of rocket measurement, but the two distributions show that a definite softening of the spectrum occurred during the period of observation. The total energy early in the flight for $E_{h\nu} > 20$ kev is about 4.5×10^{-6} erg/cm^2/sec arriving at the top of the earth's atmosphere. No X rays of $E > 20$ kev were observed in the firings conducted for background data in the absence of flares.

X-ray flux measurements were also made in the 2 to 8 A and the 8 to 20 A regions, both during quiet sun and during flare conditions. When the flare was in progress the detectors saturated, and we are at present quoting only lower limits for the incident radiation flux. Typical results during minimum and maximum phases of the solar cycle are listed in Table 1. These data confirm the existence of a large variation in X-ray emission with the solar cycle. During large flares additional increases of the over-all X-ray flux and an extension of the short-wavelength emission occur.

The results of this experiment should be compared with the flare X-ray measurements of *Peterson and Winckler* [1959]. They observed a burst of solar X rays which they estimated to

TABLE 1

Date	Counts/cm²/sec* 0.005 in. Be 2–8 A	Counts/cm²/sec* 0.00025 in. Al 8–20 A	Ergs/cm²/sec* 2–8 A	Ergs/cm²/sec* 8–20 A
1546 11/25/53	3.3×10^2†		2.9×10^{-6}	
1529 12/ 1/53		4.5×10^4		4.0×10^{-4}
1600 8/14/59	1.3×10^4	2.0×10^6	5.7×10^{-4}	1.8×10^{-2}
2253 8/31/59 (flare)	$>7 \times 10^5$	$>1 \times 10^7$	$>3 \times 10^{-2}$	$>9 \times 10^{-1}$

* Absorbing path in counters is 1.9 cm-atm of Ne. The energies calculated in the indicated spectral bands are based on an assumed 2×10^6 degree emission source normalized to give the experimental count rate per square centimeter of open window area.

† The beryllium window used in the counter flow November 25, 1953, had a surface density of 13 mg/cm² in contrast to 24.4 mg/cm² used in the other two flights.

have lasted about 18 seconds or less and whose energy at balloon altitudes peaked in the 200 to 500 kev region. On the assumption that these X rays were produced by bremsstrahlung of initially monoenergetic 0.5 to 1 Mev electrons, they concluded that the flux incident on the atmosphere must have contained of the order of 2×10^{-4} erg/cm²/sec, about 10 times the total energy above 20 Kev observed by us in the August 31, 1959, flare. The energy distribution shown in Figure 1, however, suggests a somewhat different emission character from that postulated by Peterson and Winckler. The three-decade exponential fall-off in number of quanta versus energy is inconsistent with bremsstrahlung from initially monoenergetic electrons. Such a distribution suggests bremsstrahlung from thermalized electrons, possibly an extension of the normal coronal emission. Also, the presence of quanta with $E_{h\nu} > 20$ kev in each of the three class 2+ flares measured indicates that this type of X-ray emission is probably a common phenomenon in SID flares. The balloon event, on the other hand, has been reported only once; hence, it is most likely of a rarer variety. Peterson and Winckler concluded that the flux they measured had relatively few low-energy quanta. It therefore appears that the Peterson-Winckler X-ray flash is a different phenomenon from the X-ray tail observed in the present series of experiments.

Reference

Peterson, L. E., and J. R. Winckler, *J. Geophys. Research*, *64*, 697–707, 1959.

(Received March 22, 1960.)