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ULTRAVIOLET BACKGROUND RADIATION

RICHARD C. HENRY*

The E. O. Hulburt Center for Space Research, Naval Research Laboratory,
Washington, D.C. 20390, and The Johns Hopkins University, Baltimore, Maryland 21218
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ABSTRACT

The high-galactic-latitude ultraviolet background flux has been measured and is 1900(+0, −950) photons (cm^2 s sterad Å)$^{-1}$, at 1450 Å, as seen with a 10° field-of-view detector. This is in good agreement with a value obtained by Lillie with the Wisconsin experiment on OAO-2, which had a much smaller field of view.

Subject headings: cosmology — galaxies, clusters of — ultraviolet

I. INTRODUCTION

Ultraviolet radiation observed at high galactic latitudes can be caused by direct emission from stars, scattering of the ultraviolet radiation of stars by dust, or by emission from diffuse or discrete extragalactic sources. We report here the results of observations in narrow bands centered on 1115, 1425, and 1446 Å of the flux from an empty high-galactic-latitude region and from several stars. We also set an upper limit to the flux from the Coma cluster of galaxies.

II. THE EXPERIMENT

Three ultraviolet-sensitive Geiger counters were carried on an Aerobee-150 rocket launched from White Sands Missile Range at 2230 MST on 1969 March 13. The 1115 Å detector had a LiF window and was filled with a mixture of 1 mm CH_3OH, 2 mm CH_3Br, and 760 mm of neon. The other detectors were filled with 2 mm of pXylene, 15 mm of NO, and 760 mm of neon. The 1425 Å detector had a BaF_2 window, and the 1446 Å detector had an Al_2O_3 window. Calibration consisted of comparing the response of the detectors on a vacuum-ultraviolet monochromator with that of a CsI photocell as a function of wavelength. The photocell is regularly

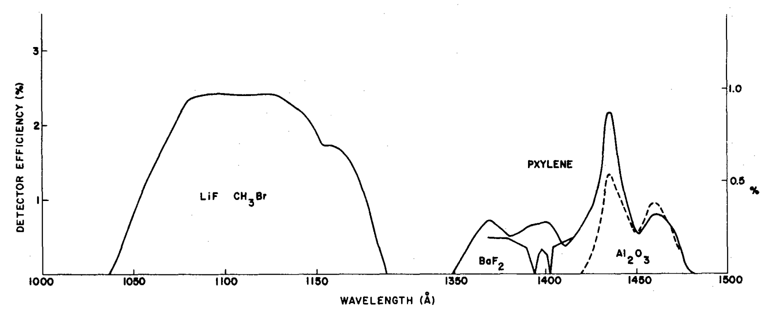

FIG. 1.—Efficiencies of the three detectors as a function of wavelength, based on calibrations before and after the rocket flight. There are different scales for the efficiency of the 1115 Å detector, and for the 1425 Å and 1466 Å detectors. Also shown is a Si IV doublet at 1400 Å from the B4 V star model of Adams and Morton (1968).

* Alfred P. Sloan Research Fellow.

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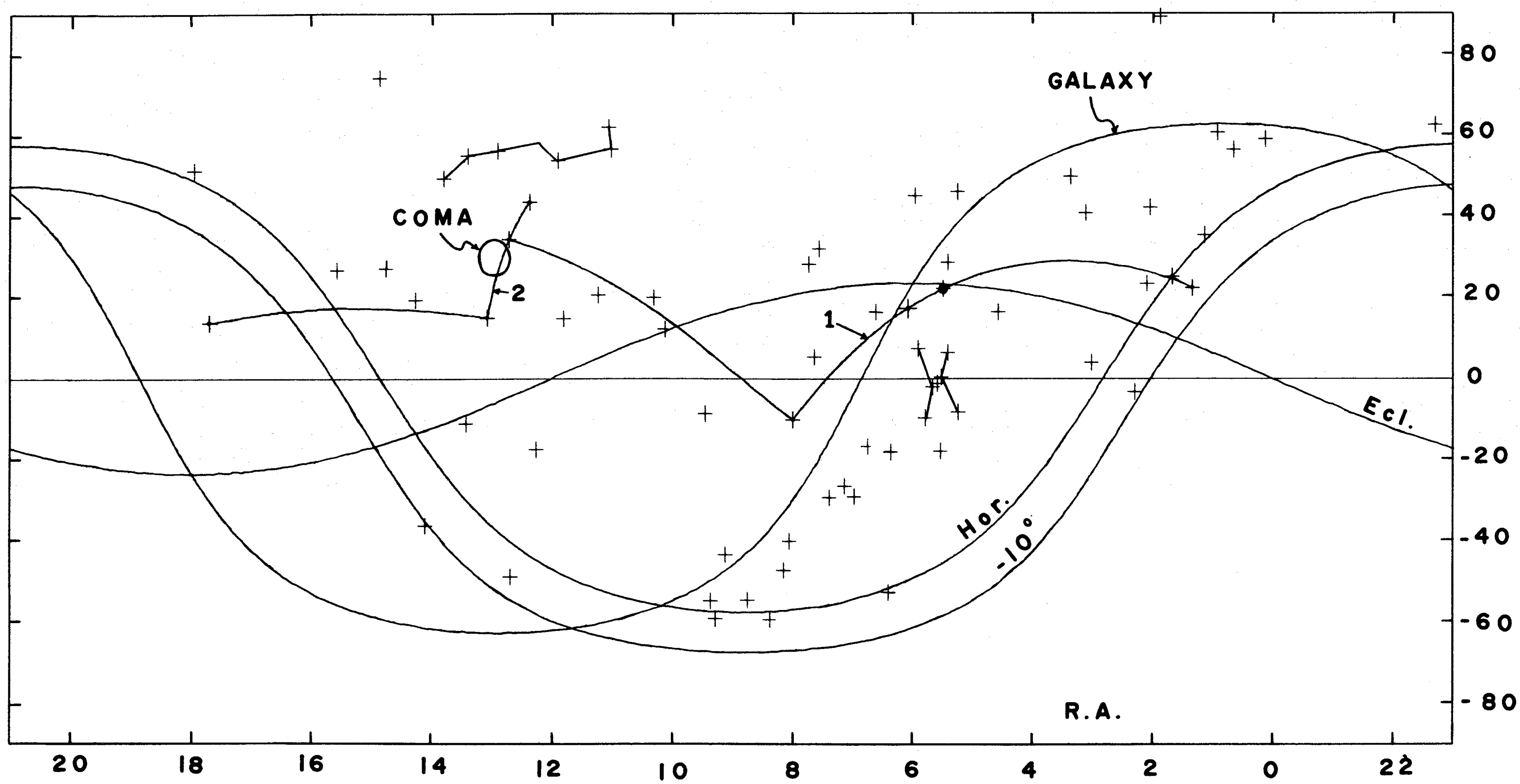

FIG. 2.—Map of the sky showing the regions scanned by the ultraviolet-sensitive detectors. Crosses indicate bright stars and the beginning and end of rocket attitude control system maneuvers. The galactic plane, the horizon, and a horizon depressed 10° are indicated. The detectors pointed initially at the horizon. They were rapidly scanned to ζ Tau, observed that star for 40 seconds, scanned rapidly to the beginning of scan 1 (marked), which was executed at 1°.05 s^{-1}. A rapid maneuver was then performed, followed by scan 2 (marked) at 0°.35 s^{-1} through the Coma cluster of galaxies.

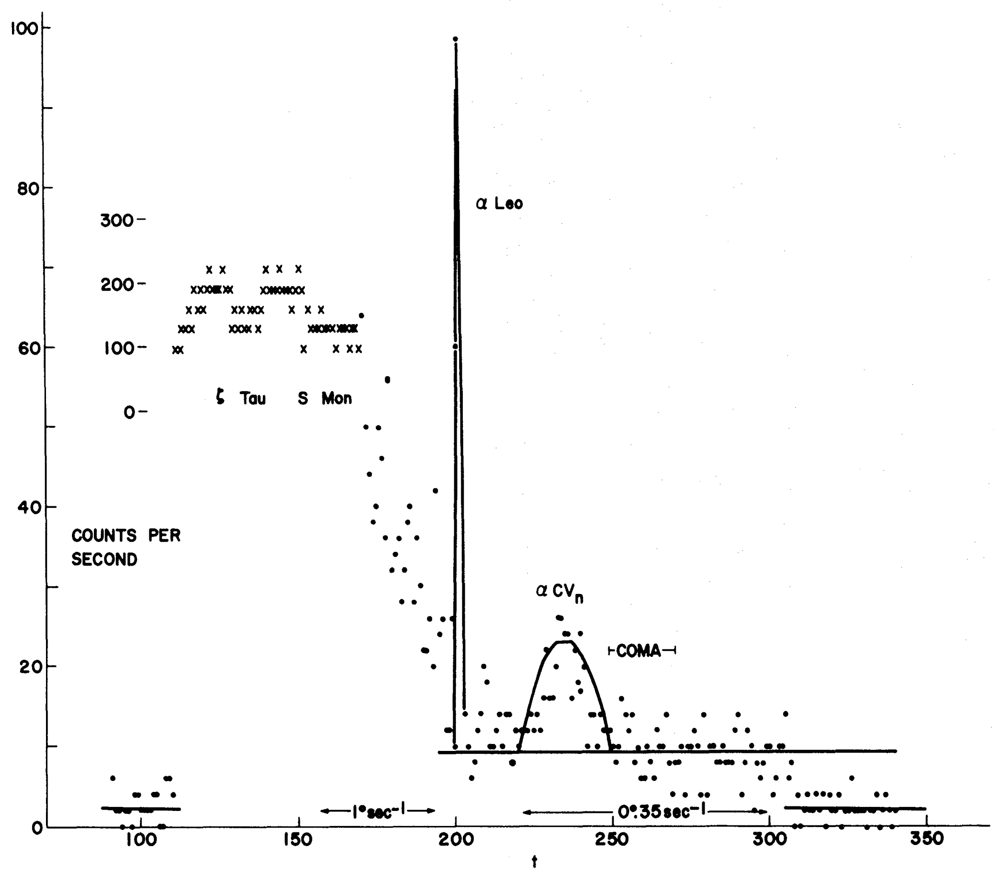

FIG. 3.—Counts per second recorded by a Geiger tube sensitive to ultraviolet radiation near 1425 Å, as a function of time. Points plotted as crosses are referred to the small inserted scale. The detector was pointed at ζ Tau, and then was scanned through the galactic plane region containing S Mon. Following a rapid maneuver to a high-latitude region, a slower scan was executed. The solid line at 235 seconds is the expected signal as a function of time for a point source 3° off the scan path. (It has been adjusted in vertical scale for best fit to α CVn.) The inside of a metal door observed early in the flight, and the flux obtained looking toward the Earth at the end of the flight, allow the cosmic-ray background to be measured.

calibrated at 1216 Å against a windowless parallel-plate methyl iodide ionization chamber. A photomultiplier, coated with sodium salicylate and assumed to have constant quantum efficiency versus wavelength, was used to extend the 1216 Å calibration to other wavelengths. Pre- and postflight calibrations agreed within ±20 percent. The mean result is shown in figure 1. The 1115 Å detector was taken to have an average efficiency of 2.4 percent and a bandwidth of 119 Å. For the 1425 Å detector, 0.34 percent and 110 Å; and for the 1446 Å detector 0.41 percent and 40 Å, were used. Pulses from the 1115 Å detector were amplified and sent to a ratemeter, for which 500 counts s^{-1} represented full-scale (5 volts telemetered to Earth). The other detectors sent pulses to amplifiers and then to scalers, which changed their telemetered output level after every two pulses received. The detectors viewed the sky directly through a ~10° FWHM collimator (2.11×10^{-2} sterad). The rocket attitude control system directed the detectors at ζ Tau for 40 seconds, and then for 40 seconds scanned the detectors along the Milky Way, through S Mon at a rate of 1°05 per second. A rapid ($6° s^{-1}$) maneuver to high latitudes caused the detectors to pass directly over α Leo. A scan of 81 seconds at a rate of 0°35 s^{-1} was executed at high galactic latitudes, passing over α CVn, the Coma cluster, and a region centered on 13^h00^m, +20°00′. The scan path on the sky is shown in figure 2, and the counting rate as a function of time for the 1425 Å detector is shown in figure 3.

III. STARS

This experiment, with its wide field of view, was designed for the measurement of background radiation. Stellar observations were intended for comparison with the observations of others as an "in-flight" calibration check. The aperture of the detectors was 0.62 cm^2. A Nikon camera aboard the rocket took photographs of the sky every 5 seconds, allowing the direction of the photometers to be determined within 0°.5. S Monocerotis was observed against a strong background of B stars, and therefore no usable data regarding its brightness were obtained. The star α Leo passed directly across the center of the field of view and was observed through the collimator with an effective area times time of 0.97 cm^2 s. The star α CVn passed 3° from the center of the field and was observed for 12.4 cm^2 s. For the α CVn observation, the background level at the other high-galactic-latitude points was subtracted. A background level was quite easy to determine for α Leo, despite the fact that the general level was changing rapidly with galactic latitude. For ζ Tau, where the rocket "held" on the star, only the high-latitude background was subtracted, because of the difficulty of estimating the correct background. The star ζ Tau should therefore appear too bright as measured in the present experiment. The observed fluxes are given in table 1. The standard errors quoted represent photon counting statistics only.

The fluxes at 1425 and 1446 Å can be compared with those reported by Smith (1967) for the same or similar stars at 1376 Å. Zeta Tauri is about 0.5 mag brighter in the present observation, as expected. For α Leo, the 1425 Å observation is in good agreement with Smith's observation, but the 1446 Å is higher by nearly a factor two. Lillie (private communication) indicates that for α Leo the average of the present 1425 Å and 1446 Å observations agrees well with a preliminary OAO photometer observation, but that the 1446 Å observation is high compared with unpublished rocket data of D. C. Evans. The present 1115 Å observation is in good agreement with the OAO spectrometer data for α Leo. For α CVn, Molnar (private communication) obtains a flux at 1450 Å of 43 photons $(cm^2\ s\ Å)^{-1}$, in good agreement with the present 1425 Å measurement. Our 1446 Å measurement is a magnitude higher. Carruthers (1969) has observed β Ori (B8 Ia); the flux that he reports relative to the visible flux is in good accord with the present measurement of α Leo (B7 V) at 1115 Å.

The present observations at 1425 and 1446 Å do not agree with each other within their errors. This is only partly due to the presence of a strong Si IV doublet in the passband of only the 1425 Å detector, as shown in figure 1. We conclude that systematic calibration errors must be present. However, the stellar calibration allows us to

TABLE 1

FAR-ULTRAVIOLET FLUX FROM STARS

Star	Spectrum	Flux, Photons $(cm^2\ s\ A)^{-1}$: Detector 1115 Å	1425 Å	1446 Å	Ratio of Count Rates 1425/1446
ζ Tau......	B2 IVp	>280	<800 ± 11	<1310 ± 21	1.38
α Leo......	B7 V	39 ± 4	370 ± 37	695 ± 80	1.22
α CVn.....	B9.5p	<17	46 ± 5.7	101 ± 12	1.04

conclude that an averaged intensity is certainly not less than the actual value, and probably not more than a factor two in excess of the actual value.

IV. HIGH-LATITUDE BACKGROUND

Near the end of the flight, while the rocket was between 126 and 94 km altitude, the detectors were pointed toward the Earth. The intensities observed can be compared with the 8 seconds of observations of the inside of the unopened door on the ascent leg of the flight, to deduce a nighttime flux from the Earth of ultraviolet radiation. The result in photons (cm^2 s sterad Å)$^{-1}$ is in table 2. The only significant flux is in the 1115 Å detector, where the signal is probably due to residual sensitivity of the detector to Lα radiation. Thus, all signals recorded with the 1115 Å detector must be regarded as upper limits only.

The flux observed at the high-latitude region is also given in table 2. The rocket was above 140 km during the observation, so absorption by the Shumann-Runge bands of atmospheric molecular oxygen should be negligible (Opal and Moos 1969). The flux observed while looking at the door has been subtracted. Averaging the values from the 1425 and 1446 Å detectors gives a background high latitude ultraviolet flux of 1900(+0, −950) photons (cm^2 s sterad Å)$^{-1}$, where the quoted uncertainty reflects the above discussion of the result of the stellar observations. This result may be compared with the upper limit of 940 photons (cm^2 s sterad Å)$^{-1}$ at 1550 Å reported by Lillie (1971), who observed with the Wisconsin experiment on the OAO-2. The agreement is excellent, particularly in view of the 10′ field of view of the OAO photometers. The much larger (10°) field of view of the present instrument would necessarily include numerous faint stars that the OAO can exclude. Comparison may also be made with the observation of Kurt and Sunyaev (1967), who obtain 56 photons (cm^2 s sterad Å)$^{-1}$ in the range 1225–1340 Å. Their field of view was of the same order as in the present experiment. It is hardly possible that the background radiation could change so drastically with wavelength, so a real discrepancy is present. Their observation was conducted from a spacecraft enroute to Venus, so perhaps we are observing radiation from some cislunar source. The OAO upper limit is, of course, also consistent with the Kurt and Sunyaev value for the flux.

The ultraviolet flux has been observed at lower galactic latitudes ($b = 0°–40°$) by Hayakawa, Yamashita, and Yoshioka (1969). They find a variation of intensity with galactic latitude from which they deduce that the light is galactic starlight plus light scattered by dust. Analysis of their data leads to an upper limit at 1400 Å of 1200 photons (cm^2 s sterad Å)$^{-1}$ for the extragalactic light.

At 1115 Å, we can also compare with the result of Kurt and Sunyaev (1970), who obtain 960 photons (cm^2 s sterad Å)$^{-1}$. Their value is consistent with our upper limit from table 2.

The present experiment also involved a scan across the Coma cluster of galaxies,

TABLE 2

ULTRAVIOLET EARTH FLUX, HIGH-LATITUDE, AND COMA CLUSTER FLUX

Detector	Flux: Photons (cm^2 s sterad Å)$^{-1}$ Earth	Flux: Photons (cm^2 s sterad Å)$^{-1}$ High-Latitude	Flux: Photons (cm^2 s Å)$^{-1}$ Coma Cluster
1115 Å.....	≤890 ± 52	≤3010 ± 45	≤2.8 ± 1.9
1425 Å.....	134 ± 273	1430 ± 110	2.6 ± 4.1
1446 Å.....	37 ± 114	2380 ± 230	6.8 ± 8.5

and upper limits to the ultraviolet flux from that cluster are also given in table 2. The Coma cluster is an X-ray emitter (Meekins *et al.* 1971; Gursky *et al.* 1971). The X-ray spectrum, whether power-law or exponential, extrapolates to the ultraviolet to produce a lower value for the predicted flux than the upper limits set here. Also, Woolf (1967), from a study of radio and optical observations, obtains a better upper limit on thermal emission than the present observations provide.

The present observation in the galactic plane is too contaminated by individual bright stars, and of too limited scope, to provide useful data.

V. CONCLUSION

The ultraviolet background level reported by Kurt and Sunyaev (1967) was sufficiently low that it was nearly possible to set interesting limits on possible hot intergalactic gas. If the present observation of a higher intensity is correct, then setting such limits through the use of ultraviolet observations will be substantially more difficult. The present observation represents a positive detection of radiation, presumably starlight, and hence was noise-limited for the detection of extragalactic ultraviolet radiation. The observation of Lillie using the OAO was a negative observation; that is, it was photon-limited. The rough agreement of the two upper limits means that a higher-sensitivity observation made "between the stars" in the OAO manner might produce a substantially lower background extragalactic ultraviolet signal level, perhaps one of cosmological significance.

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