COSMIC ULTRAVIOLET BACKGROUND RADIATION AND ZODIACAL LIGHT

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ABSTRACT
The first spectroscopic measurement of the diffuse cosmic ultraviolet background in the range 1700-2850 Å has resulted in the detection at high Galactic latitude of an intensity of 300 ± 100 photons (cm² s sr Å⁻¹) at 1800 Å without any correction necessary for starlight or airglow, a similar intensity over the range 1900-2500 Å after correction for measured airglow, and a similar intensity over the range 2500-2800 Å after correction for zodiacal light. This result agrees with some photometric measurements in the same spectral range, and also with the minimum signal has been found by many observers at shorter wavelengths. This radiation may originate partly in line radiation from a halo of our Galaxy, and partly from extragalactic sources, perhaps the integrated light of distant galaxies. We cannot completely exclude the possibility that the light is Galactic plane starlight scattered from dust, although that would require A_r > 0.1 mag in our direction of observation, which has extremely low 21 cm emission intensity. Zodiacal light is detected longward of 2200 Å, and the measured brightness and color are placed in the context of earlier observations.

Subject headings: ultraviolet; general — zodiacal light

I. INTRODUCTION
We report a new observation of cosmic diffuse ultraviolet background radiation, and of the zodiacal light, in the spectral range 1700-2850 Å. The observation was made using an Ebert spectrometer carried on an Aries rocket (24010 UG), which was launched from White Sands Missile Range, New Mexico, on 1981 April 28 at 05:25 UT (1981 April 27, 23:15 MDT).

The present observation represents the first spectroscopic detection of diffuse cosmic background radiation in this spectral range. However, recently, Henry et al. (1986) have briefly reported similar observations, from the UVX experiment carried on the Space Shuttle, from which eight regions at various locations in the sky were observed, none coincident with the present observation. The advantage of a rocket flight, compared with observation from the Space Shuttle, is that a vertical profile through the atmosphere is obtained, and residual atmospheric effects can be accurately assessed. The present observation therefore offers an important complement to the subsequent Space Shuttle observations, which will be reported elsewhere.

As will be seen below, at the longest wavelengths the observed signal is dominated by zodiacal light, which is clearly detected. At shorter wavelengths a "cosmic" signal emerges. Such a signal has been reported at shorter wavelengths (1250–1700 Å) by many observers. While there are significant disagreements among these shorter wavelength observations (see reviews by Paresce and Jakobsen 1981 and Henry 1981a), all observers seem to agree that a true "cosmic" signal, of a few hundred photon units (photons cm⁻² s⁻¹ sr⁻¹ Å⁻¹), exists over the range 1250–1700 Å. This signal may originate in a halo of our Galaxy (see Paresce, Monsignori Fossi, and Landini 1983 and references therein) or may be extragalactic, in which case it may represent the integrated light of galaxies, or may have a more exotic origin—for example, decay of primordial neutrinos (see, e.g., Kimble, Bowyer, and Jacobsen 1980; Henry and Feldman 1981; Murthy and Henry 1987). Whatever its origin, verifying the fact that this signal continues to at least 2500 Å, as we do in the present paper, is clearly important. Beyond 2500 Å, as will be seen, it is more difficult to separate any "cosmic" signal from the increasingly intense zodiacal light.

One component of diffuse emission that is expected, at some level, at moderate and high Galactic latitudes, is backscattering of the light of Galactic plane B stars. The present spectral range is of particular interest in this regard because it includes the well-known 2200 Å feature of interstellar extinction, which is widely believed to represent mostly true absorption rather than scattering. As will be seen, there is no sign in our cosmic signal of either an enhancement or a deficiency at this wavelength, but no definitive conclusion can be drawn from this fact.

The spectrometer was pointed at a single fixed target throughout the flight. As a result, excellent night airglow data were obtained (Tennyson et al. 1986, hereafter Paper I). The airglow decreased in intensity as the rocket rose, but even at peak altitude (263 km), emissions due to NO were still clearly present. Paper I provides details of the airglow spectrum and the altitude dependence, and should be consulted in order to fully assess the reliability of our present conclusions.

In the present paper we wish to determine the residual intensity after removal of signal due to airglow. The result is clearly dependent on the precision of our absolute measurement and on the reliability of our allowance for dark current. We therefore present this information in some detail, as it is critical to acceptance of the conclusion.

II. INSTRUMENTATION
The Ebert spectrometer had a focal length of 25 cm. It used a plane grating having 2160 lines mm⁻¹, with a ruled area 5.2 cm square. The entrance and exit slits were 3.0 mm × 25 mm. The sky was imaged on the entrance slit by a 27.4 cm² 25 cm focal length telescope mirror, coated with MgF₂ over aluminum (Acton No. 2000). Thus, light from a 0.69 × 5.73 (3.94 square degrees; 1.20 × 10⁻³ sr) region of sky entered the spectrometer entrance slit. Lyα radiation was excluded by mounting a 3 mm thick CaF₂ filter behind the entrance slit. The spectral range
1490–2970 Å was scanned every 10.4 s using a stepping motor and cam drive. Spectral resolution was about 50 Å. The detector was an EMR 541Q photomultiplier tube (sapphire window; proprietary photocathode).

The spectrometer was mounted on a 3/4 inch (1.9 cm) thick aluminum plate, and was aligned to the two-axis star-tracker system (Hartig, Fastie, and Davidson 1980). Alignment was better than 10", with pointing stability in flight of +30". The third-axis pointing was determined by another experiment directed out the nose of the rocket. The flight stability results from interactive television guidance by that experiment.

Calibration followed customary procedures (Fastie and Kerr 1975; Mount et al. 1977). The pre- and postflight system efficiencies (QT) are given in Figure 1. The postflight measurements were made a few months after the flight, while the preflight measurements were made a few months before the flight. Spray painting nearby during integration may be responsible for the difference. We accept the postflight calibration as correct. This decision was made on the basis of examination of the measured airglow band ratios throughout the spectral region covered, and by comparison with previous observations and theoretical predictions of NO γ- and δ-band ratios. That is, the airglow observations provided an "in flight" calibration which agrees with the postflight laboratory calibration but not with the preflight laboratory calibration.

This choice means that if the cosmic fluxes reported below are in error, it is likely that the true fluxes are lower than we are claiming. This does not, of course, affect the certainty of the detection, involving only a scale factor.

III. THE TARGET

A single target was observed continuously throughout the flight (Fig. 2). The solar zenith angle was 126°38', while the solar zenith angle at the magnetic conjugate point on the Earth was 129°9'. The Earth’s shadow’s altitude was 1600 km. At launch, the target was 61°8' above the horizon, 1°4 east of north. The rocket reached a peak altitude of 263 km, 280 s after launch.

The target was chosen to have very low 21 cm emission, <75 Heiles units (Heiles 1975). This probably indicates that there is very little dust in the field of view (Terebey and Fich 1986). There are no TD-I ultraviolet sources in the field of view, and no stars identified as early-type stars in the SAO catalog. The galaxy NGC 4605 lies near the edge of the field of view, but the data of Code and Welch (1982) predict at most 20 photon units from this galaxy.

IV. THE DATA

A small amount of electrical pickup was present on the output signal line from the photomultiplier tube. Noise spikes were particularly obvious during door opening and closing. A simple statistical filter was used to remove non-Poisson spikes. During door opening and closing, roughly 30% of the bins were found to be noise. Between these two events, only 1% or 2% of the bins were rejected by the filter. After door closing, no bins were found to be noise, except for the period 500–510 s, near the end of the flight, when a large unexplained spike was observed. The filtered data are presented in Figure 3, as a function of time.

The dark count rate, in agreement with our previous experience, was considerably higher in flight than in the laboratory. The dark count rate was determined in flight by three different methods. First, it was measured before door opening, and also after door closing, a value of 10.2 ± 3.7 counts s⁻¹ being obtained (Fig. 4). Second, data taken over the spectral range 1600–1700 Å, for the whole flight, were examined. The sensitivity of the system is near zero over this spectral range. The result was a dark count rate of 9.0 ± 2.8 counts s⁻¹. Finally, the dark count rate was left as a free parameter in the model fit to the data that is described below. This resulted in a value that is less than a standard deviation higher than the 10.2 counts s⁻¹ value obtained by observing the closed door, which value we adopt as the actual dark count (that is, the amount that has been subtracted in creating Figs. 6 and 7).

Figure 5 shows the sum of the seven spectra obtained above 257 km. These are the "raw data" on which the present paper...

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Fig. 1.—Total system efficiency, or QT, including telescope mirror reflectances (squares preflight; crosses: postflight). The postflight measurement is adopted for reasons given in the text.
is based. The feature observed at $\sim 1745$ Å may be real; this feature is discussed briefly below.

In Figure 6 the data have been corrected for dark count and system efficiency, and are compared with the results of a multiparameter chi-square fit to these high-altitude scans. The components involved in the fit are (1) residual airglow, (2) zodiacal light, (3) cosmic background, (4) dark count. The first three are folded through the slit response function and are then multiplied by the efficiency, before being added to the dark count for comparison with the data. The various components were treated as described below.

a) Residual Airglow

The residual NO $\delta$- and $\gamma$-band emission was determined by fitting a synthetic spectrum using Barth's (1965) branching ratios between the bands, as described in Paper I. The resulting

![Graph showing counts per second vs. time]

**Fig. 3**—Raw data, in counts per second, presented as a function of time. The sawtooth appearance is a result of spectral scanning; in effect, all of the individual spectra are displayed in this figure. Door opening at 90 s, and the noise spike at 510 s, are apparent in the data. The presence of geophysical sources (airglow) is apparent in the general trend of spectral intensity versus time, as the rocket rises and then falls.
(i.e., minimum chi-square) total intensity of the residual NO bands agreed quite well with the value determined from examination of altitude profiles (Tennyson 1983). The residual amount is shown in Figure 6. Notice that even at altitudes above 257 km, and observing in a direction most unfavorable for detection of airglow, a significant airglow signal is definitely present.

b) Zodiacal Light

The solar spectrum of Mount and Rottman (1981) was used, with allowance for the possibility of a constant slope, or variation in color of the zodiacal light. The best-fit result, which is shown in Figure 6, was gray across the spectral range of our observations.

c) Cosmic Background

A background of arbitrary intensity, and arbitrary but constant slope, was introduced in the form of two free parameters. The result of the fit was $300 \pm 100$ photon units, with little or no slope.

d) Dark Count

As mentioned earlier, the dark count that resulted from the chi-square fit agreed well with that determined by two other methods.

The most secure measurement of cosmic diffuse background that is apparent in Figure 6 is the intensity of $300 \pm 100$ photon units that is obtained near 1800 Å, where the corrections for airglow and zodiacal light are negligible. This inten-
sity agrees well with the minimum intensity that is found by virtually all observers at shorter wavelengths (Paresce and Jakobsen 1981). The present measurement involves no correction at all for stars in the field of view, or airglow, only for dark current and quantum efficiency.

There is clearly a cosmic signal of a few hundred units between 1900 and 2500 Å. It is worth looking in the data of Figure 6 for any evidence of the signature of the 2200 Å interstellar extinction feature; no such evidence appears.

The high-altitude spectra have been corrected for the residual airglow and zodiacal light contributions, and the result appears in Figure 7. The error bars in the figure are statistically independent errors due to original counting statistics, statistical error in each of the fits, and an assumed 10% error in the fitting routines. The systematic error due to calibration has not been included.

Most of the structure that appears in the spectrum shown in Figure 7 is not significant. The point of the figure is simply to show that very reasonable and moderately well determined airglow and zodiacal light corrections to the data of Figure 6.

Fig. 6.—Spectrum is the same as in Fig. 5, except that now the data have been corrected for dark current and instrumental sensitivity. Error bars are 1 σ in the counting statistics. The dashed line is the solar spectrum from Mount and Rottman (1981), convolved with the present instrumental response fitted to the data, with a zodiacal dust color (see text) of 0.8. Dotted (solid) lines represent the residual NO δ- (γ-) band emission that is present in the data.
produce a residual intensity of $400 \pm 200$ photons (cm$^2$ s sr Å$^{-1}$) over the range 1900–2800 Å, which is in fair agreement with the 1800–1900 Å intensity (which is much more secure).

V. DISCUSSION

The high Galactic latitude diffuse cosmic ultraviolet spectrum that appears in Figures 6 and 7 has its origin in a number of astrophysical sources.

a) Zodiacal Light

The present observation of zodiacal light may be compared with the intensity that is expected if gray scattering is assumed, to obtain a color for the zodiacal dust in the ultraviolet, following Leinert's (1975) definition of color:

$$C(\lambda_1, \lambda_2) = \left( \frac{I_{ZL}(\lambda_1)/I_0(\lambda_1)}{I_{ZL}(\lambda_2)/I_0(\lambda_2)} \right),$$

where $I_0$ is the solar intensity at the wavelength and $I_{ZL}$ is the observed zodiacal light intensity at the same wavelength. Conventionally, $\lambda_2$ is taken to be 5500 Å.

The ecliptic coordinates of our target were longitude 149°3, latitude 55°2, while the solar coordinates were longitude 37°8 and latitude 0°0055. Thus the target was at elongation 102°0 with an inclination of 57°2. To obtain the brightness of zodiacal light expected at 5500 Å at this location, the data summarized by Leinert (1975) were used. In considering the intensity variation with elongation and inclination, particular weight was given to the observations of Frey et al. (1974) and Dumont and Sanchez (1975) as suggested by Weinberg and Sparrow (1978). The resulting estimated intensity is 65 $S_{10}$ units, where an $S_{10}$ unit is one solar-type 10th magnitude star per square degree, or $6.37 \times 10^{-12}$ of the solar irradiance per steradian (Leinert 1975). We estimate the uncertainty in this value to be 20%. Comparison with the result of our chi-square fitted zodiacal light component results in a color, as defined above, for the zodiacal light of $0.80 \pm 0.32$ (see Table 1). This error is comprised of the 20% uncertainty regarding the zodiacal light intensity in the visible, 25% uncertainty in our absolute calibration, 21% uncertainty (maximum) in the Mount and Rottman (1981) solar spectrum, and a 10% statistical and fitting uncertainty. The fitting uncertainty was determined by varying the color about the best-fit value until the fitted spectrum was more than 1 $\sigma$ away from the measured spectrum in the region from 2400 to 2700 Å, where the zodiacal light is the dominant signal. As mentioned earlier, no support could be found for any variation in color over 2400–2700 Å.

Observation of zodiacal light in the ultraviolet is extremely difficult because of the low light levels involved. All previous

<table>
<thead>
<tr>
<th>Effective Wave length (Å)</th>
<th>Color</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>1.5</td>
<td>Lillie 1972</td>
</tr>
<tr>
<td>1680</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>2740</td>
<td>0.76 ± 0.1</td>
<td>Morgan, Nandy, and Thompson 1976</td>
</tr>
<tr>
<td>2950</td>
<td>1</td>
<td>Frey, Hofmann, and Lemke 1977</td>
</tr>
<tr>
<td>2150</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>2900</td>
<td>0.90 ± 0.20</td>
<td>Feldman 1977</td>
</tr>
<tr>
<td>2200</td>
<td>0.45 ± 0.25</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>&lt;40</td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td>0.54 ± 0.50</td>
<td>Pitz et al. 1978</td>
</tr>
<tr>
<td>2200</td>
<td>0.30 ± 0.09</td>
<td></td>
</tr>
<tr>
<td>2600</td>
<td>0.40 ± 0.10</td>
<td></td>
</tr>
<tr>
<td>2080</td>
<td>1*</td>
<td>Maucherat-Joubert, Cruvillier, and Deharveng 1979</td>
</tr>
<tr>
<td>2200</td>
<td>1</td>
<td>Deharveng 1979</td>
</tr>
<tr>
<td>1690</td>
<td>~40</td>
<td></td>
</tr>
<tr>
<td>2900</td>
<td>0.60 ± 0.16</td>
<td>Cebula and Feldman 1982</td>
</tr>
<tr>
<td>2900</td>
<td>0.75 ± 0.20</td>
<td></td>
</tr>
<tr>
<td>2100–2400</td>
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<td></td>
</tr>
<tr>
<td>2400–2900</td>
<td>0.80 ± 0.32</td>
<td>Present work</td>
</tr>
</tbody>
</table>

* Reanalysis of Pitz et al. 1978.
observations were broad-band photometric observations, with the exception of the Johns Hopkins spectrophotometric observations (Feldman 1977; Cebula and Feldman 1982; Henry, Anderson, and Fastie 1980). The number of observations in the ultraviolet wavelength region is extremely limited, with considerable disagreement; hence the controversy that has surrounded the true nature of the zodiacal light in the wavelength region from 1700 to 2900 Å.

The results of the OAO 2 satellite study of the ultraviolet zodiacal light showed a reddening below 3000 Å with a large upturn in the color below 2000 Å. Lillie (1972) also obtained a color of 1.5 at 1920 Å and a color of 2.00 at 1680 Å. These observations were over an elongation from 50° to 120° in the ecliptic plane at the ecliptic poles. The TD-J observations of Morgan, Nandy, and Thompson (1976) verify Lillie's results at 2740 Å with a color of 0.76 ± 0.1 at an elongation of 90°. Frey, Hofmann, and Lemke's (1977) balloon observation from the THISEB experiment package at a float altitude of 41.4 km, an elongation of 42°, and an inclination of 0° gives a solar color (i.e., a color of unity) at 2950 Å. At 2150 Å this experiment gives only an upper bound that is consistent with a solar color. The 2150 Å value has been corrected for ozone absorption but not for airglow or integrated starlight. The airglow contribution could be large, since the NO-γ-band system is in the same spectral region. The first spectroscopic observation of zodiacal light in this wavelength region was made by Feldman (1977). This experiment was at an elongation of 20° and an inclination of 10°, with a spectral resolution of 15 Å over a wavelength range of 1700–3200 Å. The spectrum showed both airglow and zodiacal light. The derived zodiacal light colors were 0.90 ± 0.20 at 2900 Å, and 0.45 ± 0.25 at 2200 Å. Feldman also obtained an upper limit a factor of 10 lower than Lillie's 1600 Å. There also was a large deviation from the solar spectrum at 2750 Å, but no complete explanation for this could be given. The Astro-7 results, reported by Pitz et al. (1978, 1979b), show the zodiacal light to be reddened compared with visible, with a color of 0.54 ± 1800 Å, 0.30 ± 0.09 at 2200 Å, and 0.40 ± 0.10 at 2600 Å at an elongation of 32° and an inclination of 4.9°. Mauchart-Joubert, Cruvellier, and Deharveng (1979) have reanalyzed the Astro-7 results, finding a color consistent with a solar color. The corrections included a change in assignment of signal from the diffuse Galactic background to the zodiacal light and a change in the effective wavelength of the 2200 Å bandpass to 2080 Å. Mauchart-Joubert, Cruvellier, and Deharveng (1979) also reported zodiacal light results from the D2B-Aura satellite, with a color consistent with solar at 2200 Å. They report a blue color at 1690 Å consistent with Feldman's (1977). An upper limit in the region 1150–1680 Å was reported by Henry, Anderson, and Fastie (1980). Cebula and Feldman (1982) reported results over a spectral range similar to that in the present experiment. These observations were made from an Astrobob-F sounding rocket at two viewing geometries with a spectral resolution of 25 Å. The first geometry, an elongation of 29.5° and an inclination of 3°, gave a color of 0.60 ± 0.16 at 2900 Å. The second, an elongation of 21:2 and an inclination of 0°, gave a color of 0.75 ± 0.20 at 2900 Å and 0.75 ± 0.20 at 2100–2400 Å. Cebula and Feldman (1982) also reported an upper limit at 1800 Å a factor of 10 lower than that of Feldman (1977), placing an upper bound on the "color" of about 4. Of importance to the present experiment is the verification by Cebula and Feldman that the zodiacal light varies spatially in the same manner in the ultraviolet as in the visible, at least over a limited range of elongation. The zodiacal light observations are summarized in Table 1.

Although there is still controversy concerning the color of zodiacal light in the spectral range of 1700–3000 Å, the values seem to be converging to a value close to solar but slightly reddened. This is consistent with the Mie theory calculations of Rösér and Staude (1978) based on grain-size measurements. The present experiment verifies the assumptions made in previous observational analyses that the spatial variation of zodiacal light is the same in the ultraviolet as in the visible, even at elongations that give minimal zodiacal light.

b) Line Emission

Turning now to the question of line emission, we note that the interstellar absorption lines of C IV and Si IV observed by Savage and de Boer (1979) have been attributed to a hot Galactic corona with a temperature of 10^5 K. Jacobsen and Paresce (1981) predicted the emission spectrum of such a hot Galactic corona based on a model with two temperature components and solar abundance. The calculated line intensities are about a factor of 100 below what can be observed at the level of sensitivity of the present experiment, and Jacobsen and Paresce argue that a factor of 100 increase in line intensity is unlikely because of pressure equilibrium considerations. Feldman, Brune, and Henry (1981) have identified four emission lines in the far-ultraviolet background observations of Anderson et al. (1979) as perhaps being due to a hot Galactic corona. The observed brightnesses were from 40 to 500 times higher than the predictions of Jakobsen and Paresce for these lines. Paresce, Monsignori Fossi, and Landini (1983) have carried out a calculation based on a new model, and have been able to reconcile the observations with a single temperature of about 1.5×10^5 K (but see also Edgar and Chevalier 1986).

Jakobsen and Paresce (1981) predict, for a hot Galactic corona, the presence of an N III line at 1749 Å with an intensity of 30 photons (cm^2 s sr)^{-1}. They also predict two other lines of possible interest to the present experiment. One is due to Si III at 1892 Å, and the other is due to C III at 1909 Å. However, both of these lines are unobservable because of the interference of the δ(0, 0) band of NO at 1909 Å in the present experiment. The N III line is interesting because it falls at the same wavelength as an observed line feature in the present data near 1750 Å. Our observed intensity for this line is quite uncertain but is ~0.25RS, i.e., 20,000 photons (cm^2 s sr)^{-1}, which is about a factor of 1000 higher than the Jakobsen and Paresce prediction. Unfortunately, the later model of Paresce, Monsignori Fossi, and Landini (1983) does not include N III.

c) Dust Scattering

Comparison of the present spectra with those of Anderson et al. (1979) suggests that at moderate and high Galactic latitudes, in addition to zodiacal light, there exists a flat spectrum with intensity of order 300 photon units from 1250 to 2800 Å (Fig. 8).

A crucial question is, is this radiation extragalactic, or is it the light of Galactic plane B stars scattering from high-latitude dust?

The traditional method of detecting an extragalactic component has been to observe the intensity of the diffuse radiation at many places on the sky and see whether the plot of intensity versus hydrogen column density has a nonzero intercept. Linear fits to the two existing sets of such data at 2200 Å are displayed in Figure 9. The three similar lines are the regressions of Jakobsen et al. (1984), who observed a limited region from an Aries rocket. The other solid straight line fits the data of Joubert et al. (1983), who observed the entire sky and who
Fig. 8.—Comparison of the present spectrum (double box) with previous data. Photometric data: P (Pitz et al. 1979a), L (Lillie and Witt 1976), T (TD-1 observations; Morgan, Nandy, and Thompson 1976), M (Joubert et al. 1983; Maucherat-Joubert, Cruvellier, and Deharveng 1980). Spectroscopic data: A (Anderson et al. 1979). Apart from the Pitz et al. observations, which may be contaminated with airglow, there is good general agreement among the various observations.

Fig. 9.—Intensity of the diffuse cosmic background at 2200 Å, as observed by Jakobsen et al. (1984; three solid lines), Joubert et al. (1983; single solid line), and us (circled dot), are compared with the 1800 Å observations of Henry et al. (1986; solid dots) and dust-scattering models (Jura 1979) at 2200 Å (broken lines; see text for model parameters). A nonzero intercept implies the presence of extragalactic radiation. The dust-scattering models are used with Burstein and Heiles' (1978) relation between hydrogen column density and $E_{B-V}$, which gives $E_{B-V} = 0$ for column densities less than 100 units (units are $2.23 \times 10^{18}$ atoms cm$^{-2}$; Heiles 1975), which may not be realistic.
report no intensities, at 2200 Å, greater than 1200 photon units.

The Jakobsen et al. (1984) photometer data were all taken below 250 km altitude, while our spectra (Fig. 6), taken above 257 km altitude, still show significant airflow contribution near 2200 Å. Because of this, and because of the disagreement with the data of Joubert et al. which were obtained at an altitude of > 500 km, we feel that the Jakobsen et al. data should not be given much weight.

We also display, in the same figure, our present 2200 Å intensity (circled black dot) and the 1800 Å UVX experiment intensities reported by Henry et al. (1986); these observers obtained very similar results at 2200 Å (Murphy et al. 1988).

For comparison with these data, we present in our figure two models following Jura (1979). We use the same parameters in Jura's model as do Joubert et al. (1983). The dashed curve has $a(1-g) = 0.5$, while the dash-dot curve has $a(1-g) = 0.15$, where $a$ is the albedo and $g$ the scattering parameter ($g = 0$ represents isotropic scattering; $g = 1$ represents completely forward scattering; and $g = -1$ represents backscattering). The fact that negative intensities are predicted for hydrogen column densities of less than 100 units results from our use of (the first two terms of) the first equation in Table 3 of Burstein and Heiles (1978); this acts as a useful caution against taking the models too seriously.

So, considering Figure 9, is there a nonzero intercept, and is there, therefore, an extragalactic signal at 2200 Å? If one considers the Joubert et al. (1983) data (and our present data point) alone, the answer to both questions is yes. (The Henry et al. 1986 data, however, provide a suggestion that the story may be more complicated; these data will be presented in detail by Murthy et al. in due course.)

Let us turn now to more detailed discussion of the present data, to see whether any clarification is possible on this question.

The data of Figure 7 are, potentially, particularly important, in that the well-known 2200 Å interstellar extinction feature occurs in this spectral range. This feature is generally agreed to be a true absorption, rather than a scattering feature, although Witt, Bohlin, and Stecher (1986) do report the presence of some scattering component. The width of this extinction feature varies from 360 to 600 Å (FWHM), depending on the line of sight (Fitzpatrick and Massa 1986). Our present data (Figs. 6 and 7) show no sign of either a peak or a dip at 2200 Å; we suggest that $I_{2200}/I_{1800} = 1.0 \pm 0.2$. Let us now discuss this absence of an effect, from two points of view: that our signal is extragalactic, and, alternatively, that it is Galactic plane starlight scattering from dust.

i) Extragalactic Hypothesis

If our signal is due to a metagalactic flux, this radiation reaches us through the interstellar dust, and must suffer particularly strong extinction at 2200 Å. If (in one extreme) all extinction is purely due to scattering, no effect should be observed. If (in another extreme) all extinction is due to true absorption at 2200 Å, and to scattering at 1800 Å, a result $I_{2200}/I_{1800} = 0.74$ is expected, for $A_g = 0.1$ mag, which corresponds to about 200 Heiles units of 21 cm emission. In fact we had fewer than 75 Heiles units at our target. We conclude that we are unable to reject the extragalactic hypothesis from our present data.

ii) Dust-scattering Hypothesis

We have calculated a large number of Jura models, using, for convenience, the 1690 Å values of $\tau_0$ and $G$ of Joubert et al. (1983) (her Table 1) as being correct at 1800 Å. The result is given in Figure 10, where bands corresponding to $I_{2200}/I_{1800} = 1.0 \pm 0.1$ are shown for various values of $A = a_{2200}/a_{1800}$, which parameter most likely has a value in the range 0.2–0.8 (the unlikely band, $A = 1.6$, is shown by dashed lines in the figure), as a function of the scattering parameters at 1800 and 2200 Å. The conclusion is that if $a_{1800} > 0.7$ (e.g., Henry 1981b), and if the 2200 Å features largely represents true absorption ($A = 0.5$ or less), then the scattering at 2200 Å must be more isotropic than at 1800 Å. Thus, we can by no means rule out the hypothesis that our signal is due to scattering from dust, from examination of the (absence of the) 2200 Å feature.

However, if our present 1800 Å absolute intensity is due to light scattering from dust, then $A_g(1-g) = 0.9$. For $g = 0.7$ this says that $A_f > 0.067$ for our target, or, for a more reasonable value of $a = 0.5$, $A_f > 0.13$ for our target. We do not
regard this value of $A_V$ as likely, and so we believe that our signal is extragalactic.

d) Other Sources

The data of Figures 7 and 8 (giving greatest weight, in Fig. 8, to spectral data, as opposed to photometry) give very slight support to the idea that a “jump” in the background intensity occurs at 1900 Å. If one cares to suggest that this ledge might be due to the presence of redshifted light from relic massive neutrinos, the parent-daughter mass is $\sim 13$ eV and the lifetime against radiative decay is $3.7 \times 10^{18}$ s$^{-1}$ (for a Hubble parameter $3.2 \times 10^{-18}$ s$^{-1}$). Stecker (1980) earlier suggested that the rise implied by the Anderson spectra, taken in conjunction with the Anderson photometry and the 1690 Å Maucherat-Joubert, Cruvellier, and Dehavreng (1979) measurement, might indicate a discrete neutrino decay feature near 1750 Å. It seems to us more likely, however, that our 1750 Å feature, if real, is due to Galactic halo atomic line emission.

Finally, the integrated light of distant galaxies must contribute to our signal. Most estimates place the expected signal an order of magnitude below our observed intensity, but Code and Welch (1982) considered evolutionary effects for their model mixes, for several models of galactic evolution. They found it possible to “brighten” the expected background by an order of magnitude, depending on the model. Thus, we cannot rule out the possibility that a significant portion of our signal has this origin.

VI. CONCLUSION

The average spectrophotometric intensity of the cosmic ultraviolet background reported by Henry et al. (1978) and by Anderson et al. (1979), agrees with the present measurement at 1800 Å, and with the present somewhat less secure measurement over the range 1900–2800 Å. Measurements using photometers, as opposed to spectrophotometry, give very diverse results. The present spectrophotometry reveals significant residual NO atmospheric emission even at 257 km altitude, perhaps accounting for some of the diversity in the photometer measurements.

Although our chi-square fits offered no support for the idea of a constant-slope variation in zodiacal light color with wavelength, or a constant-slope variation with wavelength of the true cosmic background, ultimately the cosmic signal that is detected in the spectral range longward of 2500 Å cannot be distinguished from what would be produced by a systematic change with wavelength in the albedo and/or scattering properties of the zodiacal dust particles. A complete, or at least very extended, survey of the sky would be needed to resolve this question, in order to see whether the intensity of the putative cosmic signal tracks that of longer wavelength zodiacal light.

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