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INVESTIGATION OF THE DIFFUSE ULTRAVIOLET
BACKGROUND USING SATELLITE DATA
NAG 5-449

(Dynamics Explorer Guest Investigator Program)

Final Technical Report

INSTITUTION: Department of Physics and Astronomy
The University of Iowa
Iowa City, IA 52242

PRINCIPAL INVESTIGATOR:
John D. Fix
Department of Physics and Astronomy
The University of Iowa
Iowa City, IA 52242

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I. INTRODUCTION

The imaging instrumentation for the Dynamics Explorer Mission (Frank et al. 1981) was designed primarily to obtain global auroral images. The instrument, however, has also been used successfully to study marine bioluminescence, the geocorona, and the global distribution of atmospheric ozone. The DE imager has considerable potential for the study of astronomical sources of ultraviolet radiation as well. During the tenure of grant NAG 5-449 I used data produced by the the DE imager to study the brightness and isotropy of the diffuse ultraviolet background.

II. BACKGROUND

The diffuse ultraviolet background is the cosmic ultraviolet radiation which is not attributable directly to stars in the galaxy. The nature of the diffuse ultraviolet background is of interest in both galactic and extragalactic contexts. The extragalactic component of the diffuse ultraviolet background may include contributions from quasars, galaxies, and the intergalactic medium (Paresce and Jakobsen 1980). However, there is a considerable uncertainty about the magnitude of the contributions of these sources. The extragalactic component is presumed to be isotropic, but probably would be detectable only in directions in which the galactic component is very small.

The galactic component of the diffuse ultraviolet background is thought to be primarily starlight from the galactic plane which has beens scattered by interstellar dust particles. If so, then the intensity of the galactic component at a given wavelength and in a particular direction should depend on the amount of dust in that direction, the albedo and phase function of the particles, and the amount of ultraviolet light emerging from the galactic plane. The galactic component should show a dependence on galactic latitude and may, moreover, be patchy. Certainly the interstellar gas with which ithe dust is believed to be mixed varies considerably in column density with direction (e.g., Heiles 1975). Also, there are faint, filamentary reflection nebulae at moderate to high galactic latitudes (Sandage 1976). If the diffuse ultraviolet background is radiation scattered by the same particles which produce the filamentary reflection nebulae, then the ultraviolet background would be spatially variable on a scale of a degree or less. General models of the galactic component of the diffuse ultraviolet background have been made by several investigators (e.g., Anderson et al. 1982).

There have already been a number of measurements of the diffuse ultraviolet background. The extent to which the measurements disagree about both the magnitude and isotropy of the background is remarkable. Lillie and Witt (1976) investigated the diffuse ultraviolet background by studying 71 widely distributed fields with the Wisconsin Experimental Package on OAO-2. They found a typical intensity at 150 nm of 1000 photons/ cm2 s A sr (or units, following Anderson et al. 1982) with a strong dependence on galactic latitude. Henry et al. (1977) observed about half the sky during a rocket flight. After correcting for the contribution of stars they found, at high galactic latitudes, an intensity of about 1000 to 2000 units at 150 nm. However, they attributed the radiation to airglow. Pitz et al. (1979) measured the ultraviolet background on a rocket flight and found an intensity of about 2500 units at 180 nm with little or no spatial variability. Observations with the D2B satellite were used (Maucherat-Joubert et al. 1979, Joubert et al. 1983) to find an average intensity of about 1000 units at 170 nm at high galactic latitude and a correlation with neutral hydrogen column density. Anderson et al. (1982) found the spectrum of the diffuse ultraviolet background between 118 nm and 168 nm using data from the Apollo 17 mission. They found, after correction for internally scattered light and starlight, that there was no significant residual intensity to a level of about 300 units. Voyager ultraviolet spectrometer data were used by Sandel et al. (1979) to measure an average intensity of about 5000 units at 150 nm. Finally, Paresce et al. (1980) used data from the Apollo-Soyuz mission and found that the diffuse ultraviolet background between 135 nm and 155 nm has a typical value of 800 to 1000 units with definite spatial variability. They found that intensity correlates well with neutral hydrogen column density except near the galactic poles. They also found that the minimum measured intensity was 300 units, which they suggested was attributable to the isotropic extragalactic component of the diffuse ultraviolet background.

Virtually all of the published measurements have been criticized for instrumental problems, calibration deficiencies, or contamination by local sources of ultraviolet radiation. the measurements span a factor of at least ten in the average intensity of the diffuse ultraviolet background. There is also considerable disagreement about its spatial variability. I have used DE imaging data to contribute to the resolution of these problems.

III. DE OBSERVATIONS OF THE DIFFUSE ULTRAVIOLET BACKGROUND

The DE imager scans a strip of sky 0.29 degrees wide during each spacecraft rotation (6 seconds), obtaining data for 1550 pixels at intervals of 0.23 degrees. Normally, the field of view is rotated by 0.25 degrees by means of a stepping mirror after each spacecraft rotation in order to build up an image. In order to build up adequate signal to noise, however, I have used repeated measurements of the same strip of sky in investigating the diffuse ultraviolet background. The data with which I worked were obtained on four days during July 1984 during times when DE was near apogee. The observations used filter 136W, which results in a photometric response which peaks at 150 nm and has a FWHM of 41 nm. The response at Lyman alpha is essentially zero. After the elimination of data for which the imager was pointed at earth, data dropouts occurred, or DE began to enter the trapped particle zones, 9.5 hours of usable data (22 seconds per pixel) remained. A portion of the data, showing the strip of sky at 10.6 hours right ascension from the north celestial pole to the equator is shown in Figure 1. The few identifiable stars are seen as sharp peaks about 3 pixels in width. The standard errors of the counting rates are shown below the counting rates and demonstrate that the diffuse ultraviolet background apparently has been detected at approximately the ten sigma level.

Stars in the scan line were identified using the SAO catalog. For the brighter identified stars, flux distributions from the IUE Ultraviolet Spectral Atlas and the normalized instrumental response function were used to calibrate the photometric system. The calibration has a standard error of about 10%. Pixels containing identified stars were then removed from the data. This procedure eliminated contamination of the data by stars with spectral type later than A0. O and B stars fainter than the limiting magnitude of the SAO catalog may still contribute to the data. These, however, are strongly confined to the plane of the galaxy and are a possible problem only for small galactic latitudes. After eliminating pixels contaminated by identified stars, 1350 pixels remained for further analysis.

The intensity of the ultraviolet background shows a definite dependence on galactic latitude, the precise nature of the relationship depending on galactic longitude. The ultraviolet intensity is shown against galactic latitude for galactic plane crossing near longitudes of 100 degrees and 280 degrees in Figures 2 and 3. Pixels containing stars are shown as having zero intensity. The dependence on galactic latitude is similar to that found by Lille and Witt (1976). At high galactic latitude, the ultraviolet intensity has a mean value of about 1500 units.

I have also investigated the relationship between ultraviolet intensity and neutral hydrogen column density. Figure 4 shows the relationship between the two quantities for the region with galactic latitude less than -30 degrees and between longitudes of 24 and 88 degrees. A least squares fit to the data has a slope which is nearly the same as that found by Joubert et al. (1983), who used averages over 30 square degree regions, and about 30 percent smaller than the average slope found by Paresce et al. (1980) for averages over regions of about 6 square degrees. The dispersion of points about the least squares line is also about the same as those of previous studies. However, where Joubert et al. and Paresce et al. found intensities of about 700 units and 200 units for small hydrogen column densities, the intercept of the line fit to my data is about 1100 units. Since the residual intensity in the absence of ultraviolet radiation from the galactic component is presumed to be the extragalactic component of the diffuse radiation, I have tried to be as certain as possible about the validity of the relatively large intensities which I have found. (Although a number of the published values of the average intensity are still larger.)

I have investigated the level at which the data may be contaminated by other contributions to the counting rate of the photometer. I am virtually certain that there is no zodiacal contribution, since the data show no correlation with ecliptic latitude. No contribution from trapped particles is present, since the data show no dependence on invariant latitude for the range of latitudes over which data were retained. The counting rates for times when DE was well within the trapped particle zones show that the expected rates for the greatly reduced particle fluxes at high latitudes should be negliglble. Contamination by geocoronal Lyman alpha or auroral radiation is not present, as the data show no dependence on zenith angle. The design of the DE imager ensures that scattered light cannot be a problem. A remaining concern, however, is the possible influence of galactic cosmic rays on the counting rate. I have estimated the counting rate due to Cherenkov radiation produced by cosmic rays in various optical elements of the photometer and conclude that the effect is probably small enough to be ignored. However, the possible contribution due to Cherenkov photons as well as the contribution due to direct cosmic ray hits on the photomultiplier tube requires experimental investigation. I have proposed for (and will recieve) another DE Guest Investigator Grant to study this problem. This will be done by measuring the counting rates using filter 136W (which was used for the data which have already been taken) and filter 136N, for which the wavelength of peak response is the same as that of 136W, but which has a sensitivity of only about 50%

that of 136W. The precise value for the relative instrumental sensitivities of the two filters will be found using data for bright stars. By comparing the minimum counting rates using the two filters it will be possible to distinguish between the contribution to the background which is due to cosmic ultraviolet background (and would be reduced by the same ratio as the intensity of bright stars when using the narrower filter) and any other source of counts, which would be unchanged. The data for this study have already been acquired (in November 1985 and March 1986). Analysis will be carried out as soon as the data (and orbital information) are available from the DE imaging team. When this is finished the calibration of the data on the diffuse ultraviolet background can be completed and the study can be published.

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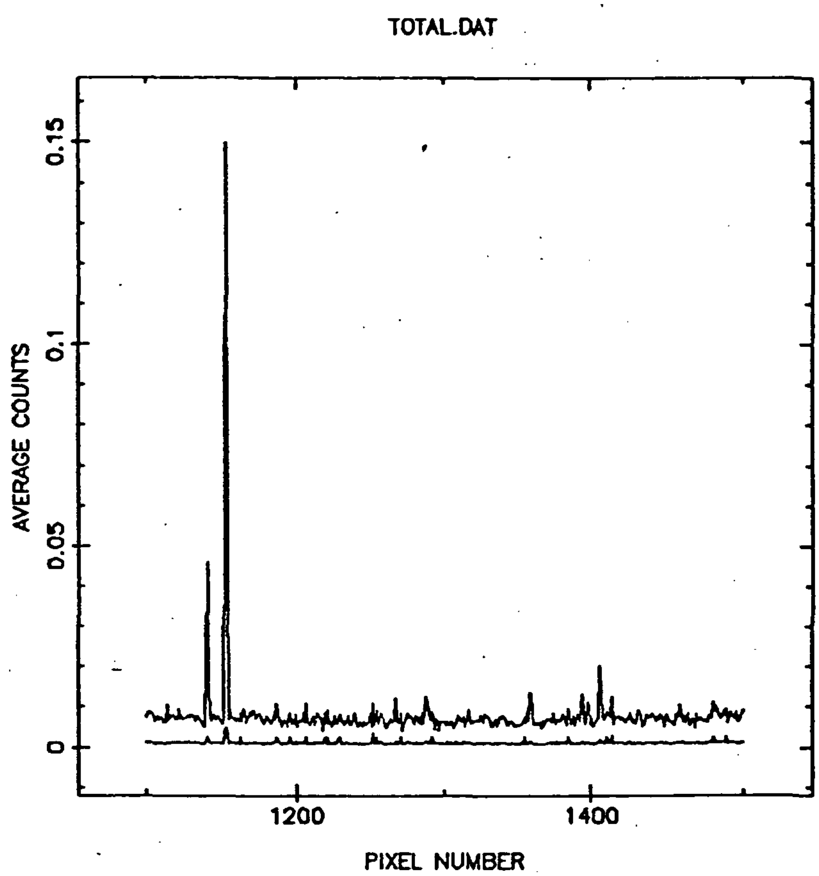

Figure 1. The average counting rate at 10.6 hours right ascension between the north celestial pole and the celestial equator.

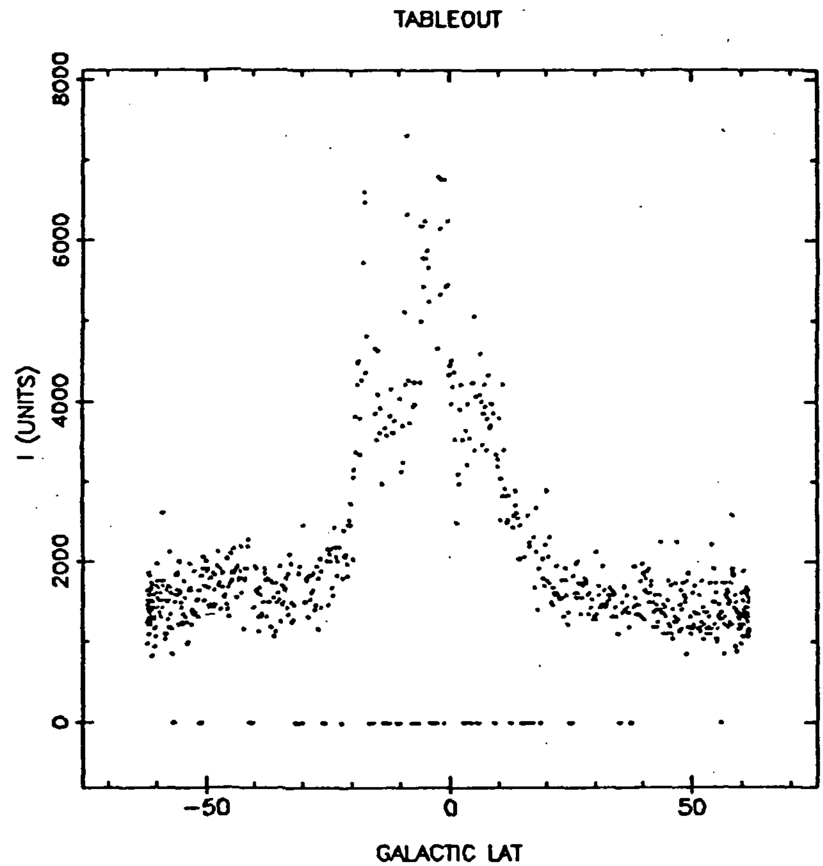

Figure 2. Ultraviolet intensity versus galactic latitude near galactic longitude 100 degrees.

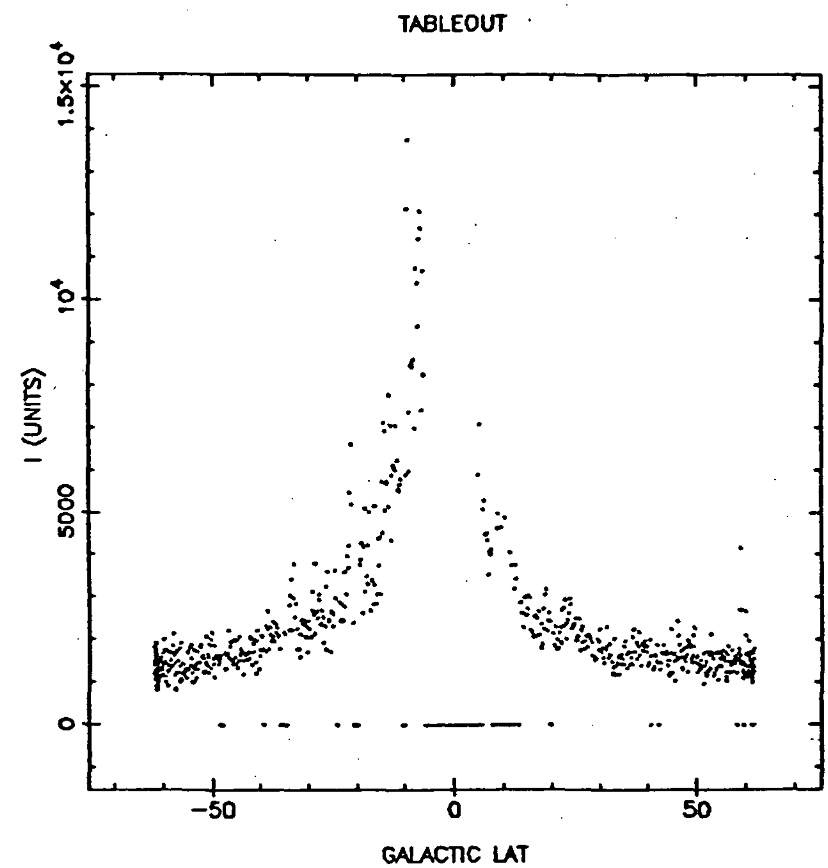

Figure 3. Ultraviolet intensity versus galactic latitude for near galactic longitude 280 degrees.

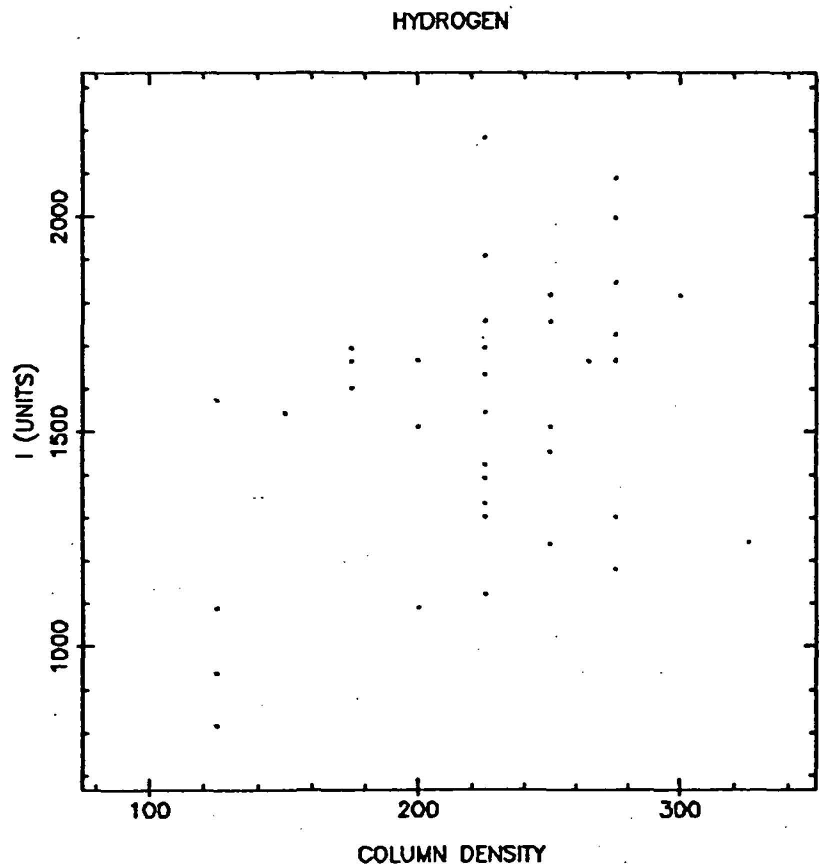

Figure 4. Ultraviolet intensity versus neutral hydrogen column density at high galactic latitude. The neutral hydrogen column density is shown in units of 2.23 x 10**18 per square centimeter.