# THE EXTRAGALACTIC COMPONENT OF THE ULTRAVIOLET SKY BRIGHTNESS

Charles F. Lillie
The University of Colorado
Boulder, Colorado

ABSTRACT

The surface brightness of the night sky has been measured at 12 wavelengths in the 1250-4300 Å spectral region with the stellar photometers on OAO-2. From observations at high galactic latitudes it is possible to set upper limits on the brightness of the extragalactic sky background at several wavelengths. In the wavelength range 1420-1680 Å the extragalactic background is not greater than $1.2 \times 10^{-8}$ ergs $cm^{-2}s^{-1}ster^{-1}Å^{-1}$. Observations of nearby galaxies with OAO-2 are used to predict the background due to extragalactic nebulae. It is shown that instruments which are an order of magnitude more sensitive would be required to detect the extragalactic component of the light of the night sky.

## I. INTRODUCTION

In principle, measurements of the surface brightness of the extragalactic sky should provide a sensitive test for cosmological models of the universe and provide information on the density and temperature of the intergalactic gas.

In practice, however, the extragalactic light is only a minor component of the light of the night sky (LONS) when compared with the contribution of scattered light, airglow, zodiacal light, integrated starlight and diffuse galactic light (Roach and Smith 1968). Thus present observations only provide upper limits to the brightness of the "cosmic light." It is apparent that observations from above the atmosphere are necessary to reduce the contribution of the other sources of the LONS.

Observations from vehicles in earth orbit avoid the contributions of atmospheric scattering and airglow which contribute about a third of the LONS. When it becomes possible to send vehicles beyond the orbit of Saturn, the contribution from the zodiacal light can also be avoided and the extragalactic light should become a measurable quantity.

Kurt and Sunyaev (1970) have suggested that the contribution from the zodiacal light can also be minimized by observing in the 1000-2000 Å spectral region where the solar flux is down by 2 or 3 orders of magnitude from the visible. In addition, nearly all the starlight in this spectral region is from early-type stars which are not numerous near the galactic pole and can easily be avoided with an instrument having a small field of view.

Since the stellar photometers in the Wisconsin Experiment Package on OAO-2 meet these criteria, we felt it would be useful to present the limits to the surface brightness of the extragalactic sky which can be set with this experiment. In addition, we use the results of OAO observations of nearby galaxies to predict the contribution to the LONS from extragalactic nebulae.

## II. OBSERVATIONS

The instrumentation and operation of the Wisconsin Experiment Package (WEP) on OAO-2 have been discussed in detail by Code *et al*. (1970). Observing techniques and data analysis for sky background measurements are discussed by Lillie (1972) and Witt and Lillie (1972). Briefly, the surface brightness of the night sky can be measured with the four stellar photometers of the WEP. These photometers have 12 medium band filters covering the 1000-4000 Å spectral region. With a 10 arcminute field of view, the sky background can be detected in a 64-second integration time using the digital data output. The precision of this digital readout is one count (which represents 64 photoelectric events).

The sky background data which we present was obtained by observing regions of the sky near the galactic poles in which there were no stars brighter than 10th magnitude.

The galaxy data was obtained by the observation of bright, nearby galaxies which could be detected with WEP.

## III. RESULTS

### a) Upper Limits to the Extragalactic Background

In Table 1 we present the upper limits to the extragalactic sky brightness determined from OAO data compared with those

Table 1. Upper Limits to the Surface Brightness of the Extragalactic Sky.

| Author | Wavelength $\lambda$ | Brightness $F_\lambda$ (1) | $F_\nu$ (2) |
|---|---|---|---|
| Roach and Smith (1968) | 5300 Å | $6.6 \times 10^{-9}$ | $6.2 \times 10^{-20}$ |
| Roach (1971) (3) | 5300 | 2.4 | 2.2 |
| DeVaucouleurs (1949) (4) | 4300 | 1.2 | 0.8 |
| Lillie (1968) | 4100 | 2.4 | 1.5 |
| Hayakawa *et al*. (1969) | 1415 | 17.0 | 1.1 |
| Kurt and Sunyaev (1970) | 1283 | 1.8 | 0.1 |
| Kurt and Sunyaev (1970) | 1115 | 17.0 | 0.7 |
| Present Study | 2460 | 0.74 | 0.15 |
| Present Study | 2030 | 2.2 | 0.30 |
| Present Study | 1910 | 4.9 | 0.60 |
| Present Study | 1550 | $12.0 \times 10^{-9}$ | $0.95 \times 10^{-20}$ |

(1) ergs/cm$^2$-sec-Å-ster
(2) ergs/cm$^2$-sec-ster-Hz
(3) a tentative measurement
(4) calculated from galaxy counts

from previous observations. The OAO data is for four wavelengths at which no residual signal could be found after correcting for instrumental effects (dark current, substrate scintillation) and removing the contribution from zodiacal light (Lillie 1972). It was thus assumed that no extragalactic signal greater than one count could be present. Data from the other filters is not presented because of known red leaks and uncertainties in removing the contributions of integrated starlight and zodiacal light. The absolute flux equivalence of one count was found with an interim calibration for the WEP photometers which should be accurate to ±20%.

It is important to note that two of the values in Table 1 are not upper limits. De Vaucouleurs (1949) has calculated the surface brightness of the extragalactic sky to be expected on the basis of galaxy counts and Roach (1971) has extended the analysis of his sky background data (Roach and Smith 1968) to arrive at a tentative measurement of the extragalactic light.

### b) The Background from Extragalactic Nebulae

In order to predict the ultraviolet background due to extragalactic nebulae, we have constructed a composite galactic spectrum using OAO observations of nearby galaxies. The data used in this study are shown in Figure 1. The curve for an Sa galaxy is a linear extrapolation from the Sb and Sc data. A more complete description of the ultraviolet energy distribu-

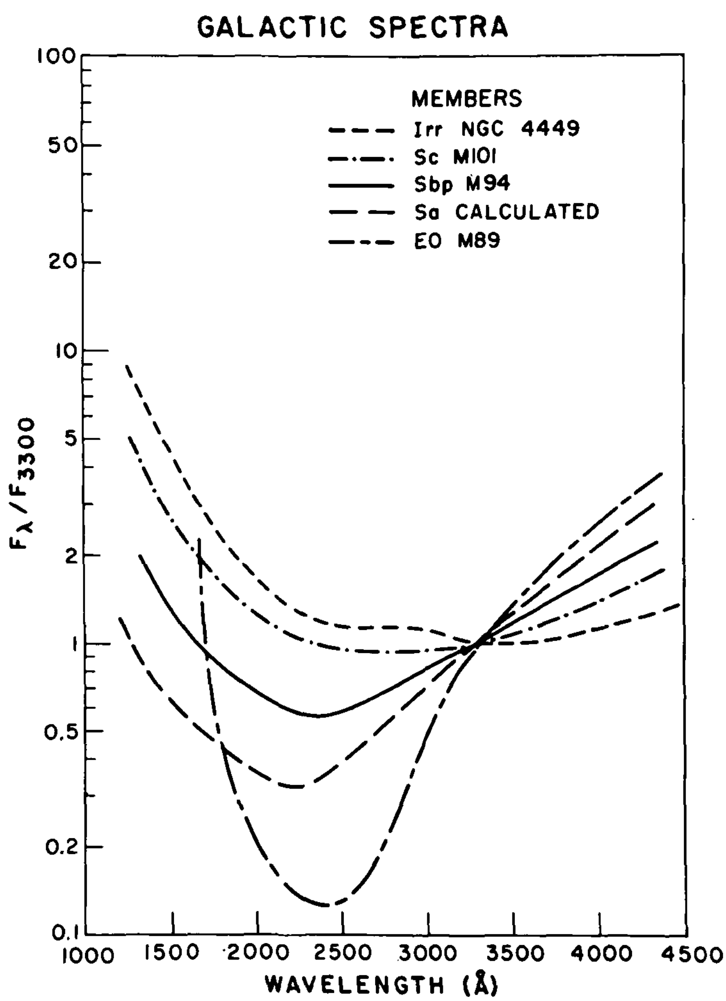


*Figure 1.—Galactic spectra for a range of morphological types in the 1000-4500 Å spectral region.*

tion of galaxies has been presented by Code, Welch and Page (1972). The upturn in the E0 galaxy spectrum is based on a very small signal and may not be real. The other spectral features repeat well from one galaxy to another.

The calculations follow a similar computation by Kurt and Sunyaev (1967) and are summarized in Table 2.

The composite spectrum which we derive is essentially that of an Sb galaxy with an enhancement below 2000 Å due to S0 and elliptical galaxies. The effects of evolution and the Hubble red shift are not considered in these calculations, so the spectrum is that of a static, Newtonian universe.

In Figure 2 we show the composite spectrum, normalized to the galaxy counts of De Vaucouleurs, along with the observed upper limits to the surface brightness of the extragalactic sky from Table 2. We show the case in which there is no upturn in the spectrum of elliptical galaxies below 2000 Å. We also show the extragalactic background predicted by Kurt and Sunyaev (1970) for the hot, diffuse, intergalactic gas which, presumably, would be present if the universe is closed by luminous matter.

The effect of the red shift on our composite spectrum can be estimated with the calculations of McVittie and Wyatt (1959). They computed the flux density for a Milne universe in which recessional (but not gravitational) effects are considered and compared with that from a Newtonian universe. The effect of recession is to enhance the infrared and deplete the ultraviolet spectral region. In Figure 2 the composite spectrum for a Milne universe normalized to 4300 Å would be a factor of 1.3 brighter than that for a Newtonian universe at 5300 Å and a factor of 3.7 fainter at 1380 Å.

## IV. CONCLUSIONS

The purpose of this study was to examine the upper limits to the surface brightness of the extragalactic sky which can be set with observations from the Wisconsin Experiment on OAO-2 and to estimate the background which would be expected from extragalactic nebulae on the basis of OAO observations of nearby galaxies.

From the results, shown in Figure 2, we can draw several conclusions:

1. The instrumental sensitivity of the OAO photometers would have to be increased by about an order of magnitude in the 1000-2000 Å spectral region to detect the extragalactic component of the "light of the night sky."

2. The background due to extragalactic nebulae is of the same order of magnitude as the radiation from the intergalactic gas predicted by Kurt and Sunyaev (1967) and not, as they

Table 2. Composite Galactic Spectrum for a Newtonian Universe

| Type of Galaxy | E | SO | Sa | Sb | Sc | Sd | Sm | Irr | Composite |
|---|---|---|---|---|---|---|---|---|---|
| % | 22 | 18 | 12 | 15 | 19 | 8 | 3 | 3 | 100 |
| Mpg | -14 | -16 | -18 | -19 | -17 | -16 | -16 | -15 | -19 |
| Effective % | 0.9 | 5.2 | 18.8 | 60 | 12 | 2.2 | 0.7 | 0.3 | 100 |

| Observed Galaxy, $f_{\lambda}/f_{3330}$ $\lambda$ | M 89 | Calc | M 94 | M 101 | NGC 4449 | |
|---|---|---|---|---|---|---|
| 4250 | 2.19 | 2.80 | 2.05 | 1.61 | 1.21 | 2.14 |
| 3330 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2980 | 0.47 | 0.68 | 0.57 | 0.95 | 1.10 | 0.65 |
| 2460 | 0.13 | 0.37 | 0.56 | 0.95 | 1.12 | 0.56 |
| 2380 | 0.13 | 0.35 | 0.65 | 0.96 | 1.16 | 0.61 |
| 2040 | 0.19 | 0.34 | 0.74 | 1.21 | 1.53 | 0.71 |
| 1680 | 1.60 | 0.50 | 0.97 | 1.89 | 2.80 | 1.07 (0.89) |
| 1500 | 20.3 | 0.64 | 1.30 | 2.62 | 4.30 | 2.57 (1.32) |
| 1380 | 200 | 0.86 | 1.71 | 3.95 | 8.80 | 14.16 (1.84) |

Values in parentheses are for the assumption of no contribution from E-galaxies below 2000 Å.

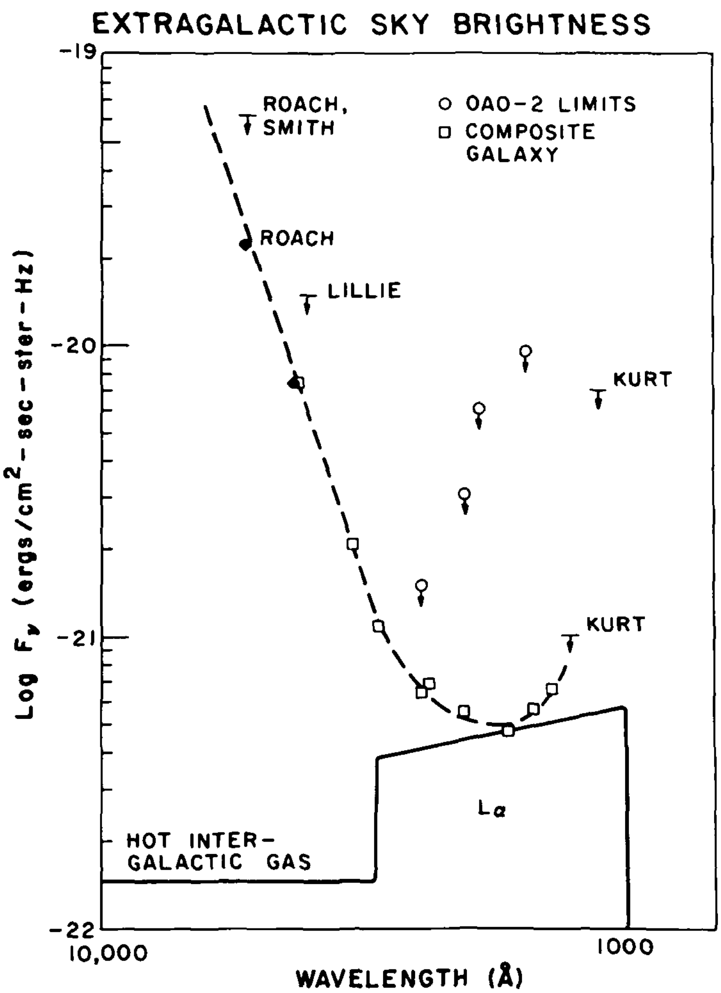


*Figure 2.—Upper limits to the extragalactic sky brightness compared with the flux predicted for the hot intergalactic gas and a composite galactic spectrum for a Newtonian universe.*

suggest, two orders of magnitude fainter. Thus, the detection of an intergalactic gas will be much more difficult.

3. In both the Milne and Newtonian universes the assumption of an upturn in the spectrum of elliptical galaxies below 2000 Å would lead to a surface brightness for the extragalactic sky which exceeds the upper limits of Kurt and Sunyaev.

It is possible that a rigorous analysis of the 2980 and 3300 Å data from OAO-2 will permit additional limits to the brightness of the extragalactic sky to be set. But it appears that direct measurements of the extragalactic light in the 1000-2000 Å spectral region require an instrument which can detect a surface brightness of $10^{-22}$ ergs/cm$^2$ - sec - ster - Hz. Measurements in the visible and near ultraviolet require instruments which can be carried to the outer part of the solar system so the contribution of the zodiacal light to the LONS may be avoided.

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## REFERENCES

Code, A. D., Houck, T. E., McNall, J. F., Bless, R. C. and Lillie, C. F. 1970, Ap. J. 161, 377.
Code, A. D., Welch, G. A. and Page, T. L. 1972, this volume.
De Vaucouleurs, G. 1949, Ann. Astrophys. 12, 162.
Hayakawa, S., Yamashita, K. and Yoshioka, S. 1969, Astrophys. Space Sci. 5, 493.
Kurt, V. G. and Sunyaev, R. A. 1967, Cosmic Research 5, 496.
__________ 1970, I.A.U. Symposium, No. 36, p. 341.
Lillie, C. F. 1968, Thesis, University of Wisconsin.
__________ 1972, this volume.
McVittie, G. C. and Wyatt, S. P. 1959, Ap. J. 130, 1.
Roach, F. E. and Smith, L. L. 1968, Geophys. J. R. Astr. Soc. 15, 227.
Roach, F. E. 1971, private communication.
Witt, A. N. and Lillie, C. F. 1972, this volume.