DIFFUSE GALACTIC LIGHT IN THE 1500-4200 ANGSTROM REGION

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ABSTRACT

Diffuse galactic light has been observed with the four stellar photometers of the OAO-2 in 29 of Kapteyn's selected areas. The data can be understood in terms of a wavelength dependent albedo of the interstellar grains with a pronounced minimum around 2200 Å with a rapid increase towards unity at wavelengths below 2000 Å.

I. INTRODUCTION

The properties of the interstellar particles must be deduced from observational material on their extinction, scattering and polarization of starlight. Uncertainties arise in the interpretation of this data because the observations are not perfectly accurate and because several theoretical models may fit the data.

The success of OAO-2 has made it possible to obtain extensive observations of interstellar extinction and the diffusely scattered galactic radiation in the 1000-4000 Å spectral region. The extinction curve for this region is well-established from rocket and OAO observations (Stecher 1965, Bless and Savage 1972). Since extinction is the sum of scattering and absorption, a measurement of the albedo of the interstellar dust and its change with wavelength permits us to determine the wavelength dependence of the particles' scattering efficiency and absorption efficiency separately. Such information aids significantly in studies of the nature of interstellar dust grains, their temperatures and the related infrared radiation and in the calculation of the interstellar radiation field.

In this paper we present the results of a program to extend measurements of the diffuse galactic light (DGL) into the ultraviolet using the stellar photometers in the Wisconsin Experiment Package (WEP) on OAO-2. Our approach was to measure the surface brightness of the sky background in Kapteyn's selected areas for which detailed star counts are available. After removing the contributions due to zodiacal light and direct starlight, we find a residual which we identify as diffuse galactic light. We computed the ratio of DGL to direct starlight and compared it with models to find the albedo and asymmetry factor of the interstellar particles. Combining extinction data with our albedo determinations, we then calculate scattering and absorption efficiencies for the interstellar grains.

II. THE OBSERVATIONAL MATERIAL

The instrumentation and operation of the Wisconsin experiment has been described in detail by Code et al. (1970). For this investigation we used the four stellar photometers with the 10-arc-minute diameter field of view to measure the surface brightness of the night sky in 29 of Kapteyn's Selected Areas at twelve wavelengths between 1050 and 4200 Å. In most cases, we centered the central star in the field of view.

A typical observing sequence consisted of eleven measurements with each photometer: two dark readings, a calibration reading and eight readings (3-2-3) with the three medium band filters. It required 24 to 32 minutes to complete, depending on the integration times used.

The reduction of these observations was complicated by a time dependent dark current induced by charged particles trapped in the earth's radiation belts. The dark current was typically 50% of the total signal and care had to be exercised in removing it.

The data reduction procedure consisted of first plotting the dark current readings as a function of time and then interpolating to find the proper correction for each measurement. For stellar photometers 3 and 4 an additional correction was necessary to account for the signal induced by beta-particles from the Cerenkov radiation source used for calibration and for fluorescence in the calcium-fluoride substrate of some filters.

After finding the net digital counts from the sky background in this manner, we then removed the signal attributable to zodiacal light on the basis of a separate study by Lillie (1972). The data were then converted to units of AOV stars of magnitude

V = $10^{m}_{.}0$ per square degree using stellar observations with the same instruments.

III. CORRECTIONS FOR STARLIGHT

The choice of selected areas as regions to be observed was inspired by the fact that detailed starcounts are available for these areas. In this way we were able to determine relatively reliable corrections for the integrated starlight included in the diaphragms of the photometers. The principal difficulty in using the photographic magnitudes of the starcount data was found to be in the uncertainty of the magnitudes in some of the brighter stars contained in our fields. Consequently, we used a 16-inch telescope at the Kitt Peak National Observatory to determine photoelectric magnitudes and colors in the UBV system for those stars brighter than 11th magnitude which we were able to reach from that location. These measurements were also used to establish a transformation relation between the photographic and the photoelectric B magnitudes, allowing us to eliminate at least systematic effects from the magnitudes of those southern stars which we were not able to observe directly from Kitt Peak.

The integrated light of the fainter stars was determined from the _Harvard-Groningen Durchmusterung of Selected Areas_ and the _Mount Wilson Catalogue of Photographic Magnitudes in Selected Areas 1 - 139_.

After the total starlight correction in one wavelength bandpass is secured, one faces the additional problem of determining the corresponding starlight correction in the observed ultraviolet wavelength bandpasses where no starcounts are available. This was solved in a two-fold way. The brighter stars, for which colors are available, were transformed individually using photometric data from the OAO for stars of similar spectral characteristics as a guideline. The fainter stars were dealt with collectively, using for transformation the predictions made with the help of a photometric Milky Way model, which was used previously by Witt (1968) and Lillie and Witt (1969). This model utilizes a distribution of stars and interstellar dust in an idealized galaxy, which produces integrated starlight with properties very similar to those derived from actual starcounts in our galaxy. By the use of transformations of the luminosity function into bandpasses of shorter wavelengths, based on OAO photometry, and by appropriate scaling of the interstellar extinction detailed information concerning the integrated star background in the ultraviolet can be generated.

IV. ANALYSIS OF RESIDUAL BACKGROUND RADIATION

The residual obtained after subtracting the corrections for zodiacal light and integrated star background from the measured surface brightness was interpreted as diffuse galactic light (DGL). DGL is assumed to be due to starlight scattered in interstellar space by dust grains. Figure 1 shows the resulting DGL intensity at 4250 Å, plotted against galactic latitude. We have performed sliding averages over three consecutive points in order to demonstrate more clearly the concentration towards the galactic plane. Only part of the scatter is due to uncertainties; largely it reflects the real variation of DGL intensity with galactic longitude. The results at the other OAO bandpasses are very similar.

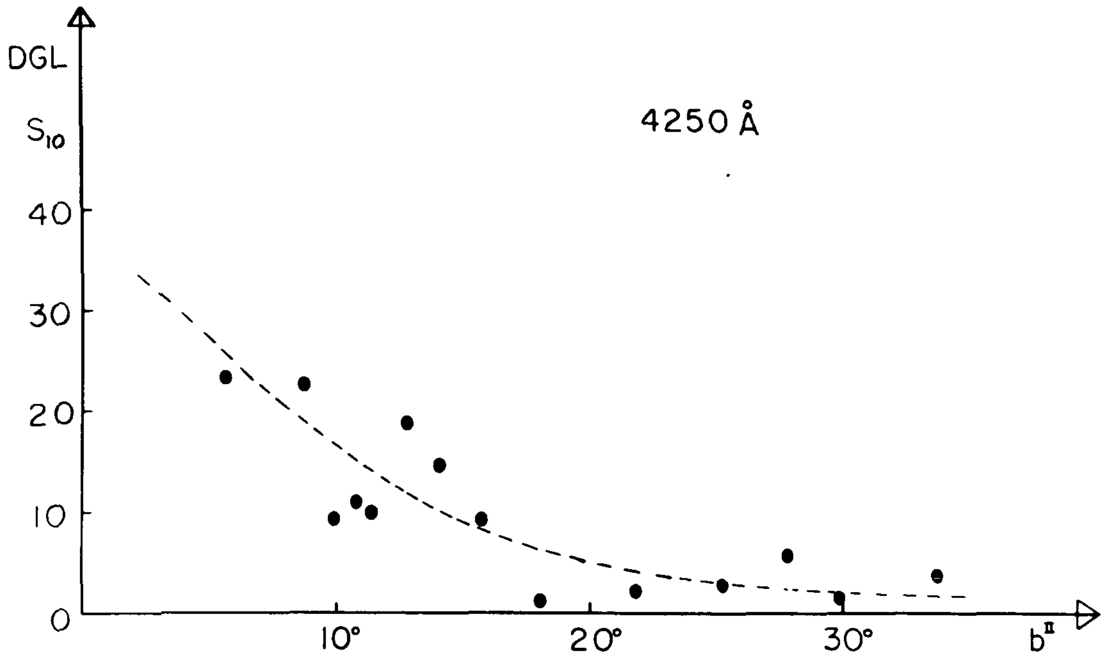

Figure 1.—Residual background radiation as a function of galactic latitude.

For the interpretation of these measurements we used the recent models for the radiative transfer of DGL including multiple scattering which were calculated by van de Hulst and de Jong (1969). From their tables we calculated the ratio of DGL to line-of-sight starlight as a function of galactic latitude, using the albedo, a, of the dust grains and the asymmetry factor, g, of the scattering phase function as free parameters, to be determined by comparison of the model with the observational data. The line-of-sight starlight for the observed selected areas was obtained by integration of the starcounts in Groningen Publication No. 43. The optical thickness of the galactic layer was taken to be 0.3 at 4250 Å and was assumed to reach 0.4 at 2000 Å.

Ratios of measured DGL to line-of-sight starlight were formed for all observed areas and a best fit was found out of the series of model predictions for each wavelength bandpass. Thus, combinations of a and g were found.

V. RESULTS

Figure 2 shows the albedo, a, as a function of wavelength between 4250 and 1500 Å. The outstanding features are the pronounced decrease in albedo around 2200 Å, which is coincident in wavelength with the "hump" observed in the interstellar extinction curve and the sharp rise of albedo at wavelengths shorter than 2000 Å. The vertical error bars are estimates based on combined uncertainties in the observations and the radiative transfer model; the horizontal error bars reflect the finite width of the filters. The measured points are plotted at the position of the effective wavelength of the filters. Note at this point the striking similarity between

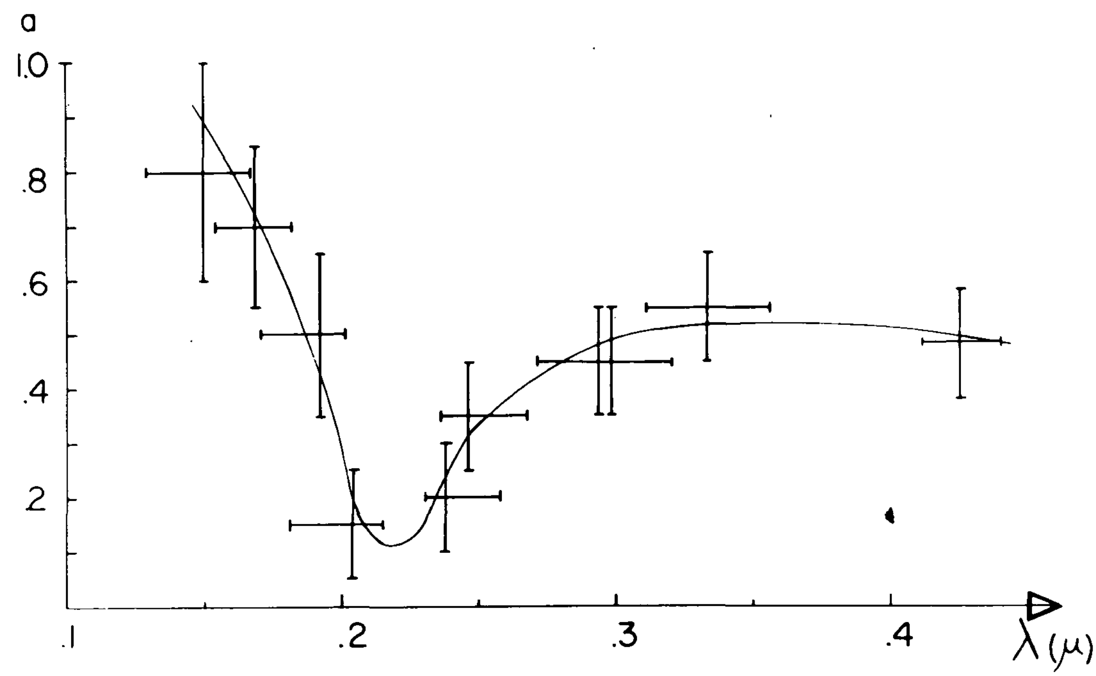

Figure 2.—Albedo of the interstellar particles as a function of wavelength.

the albedo variation of interstellar grains and the curves of the wavelength dependence of the zodiacal light brightness found by Lillie.

One may now attempt to use the results shown in Figure 2 in combination with the interstellar extinction in the ultraviolet, as determined by Bless and Savage, to derive separately the efficiencies for scattering and absorption for the interstellar grains. This becomes possible since extinction is the sum of scattering and absorption and albedo is the ratio of scattering to extinction efficiency. Figure 3 shows the result of such calculations based on the observed wavelength dependence of albedo and extinction. It shows clearly the pure absorption nature of the "hump" in the extinction curve. The low albedo around 2200 Å is caused by this strongly increased absorption efficiency rather than a drastically decreased scattering efficiency. The renewed rise of the extinction curve below 2000 Å seems to be caused by a process of pure scattering.

Care should be applied when comparisons are attempted between theoretical models and our albedo curve or the scattering and absorption efficiency shown in Figure 3. The convolution of the DGL spectrum with the finite filter widths has to be taken into account.

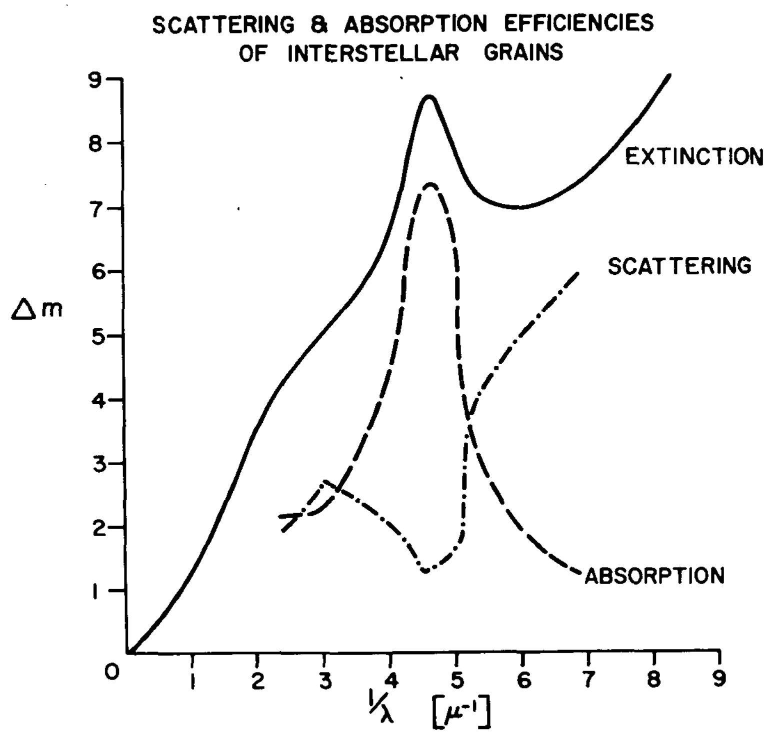

Figure 3.—Wavelength dependence of scattering and absorption efficiencies of interstellar grains. Heavy curve is the extinction curve of Bless and Savage.

The asymmetry factor, g, of the scattering phase function of the interstellar grains may be estimated from the variation of the ratio of DGL to line-of-sight starlight with galactic latitude. The observed ratios for all bandpasses above 1900 Å decrease significantly with increasing galactic latitude, thus indicating a strongly forward scattering phase function, with $g = 0.75$ representing the average estimate. At 1680 Å and 1500 Å, the DGL appears much less concentrated towards the Milky Way, suggesting a tendency for the phase function towards isotropy.

We feel that this result together with the rapidly increasing albedo in the same part of the spectrum may be indicative that either a new particle component becomes important for wavelengths below 2000 Å or that a new scattering process becomes active in this region.

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