OPTICAL CHARACTERISTICS OF GALACTIC 100 μm CIRRUS

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Variations in the optical surface brightness of the night sky on angular scales of arcseconds to degrees are contributed to by phenomena ranging from geophysics to cosmology. Known time-independent (over years) sources include (1) fluctuations in the distant galaxy distribution and (2) scattered disk light off dust in the plane of our galaxy and at high latitudes (*IRAS* cirrus; Low et al. 1984). Sandage (1976) found optical "cirrus" on photographic plates, which were later correlated with bright 100 μm cirrus (de Vries and Le Poole 1985). We describe here a systematic investigation of fainter and more widespread high-latitude *IRAS* cirrus using deep multicolor charge-coupled device (CCD) imaging photometry (Guhathakurta and Tyson 1989).

The optical data presented here were acquired using the 1.1 m telescope at Lowell Observatory with an RCA CCD, binned 2 × 2 (2.7″ pixel^{-1}) to improve sensitivity. Three filters were used: B_J, R, and I, centered at 4500 Å, 6500 Å, and 9000 Å, respectively. Since the cirrus is often extended on scales larger than a single CCD frame (8′), we had to modify the in-field chopping technique of Tyson (1988). A CCD mosaicing method is used, allowing us to map areas as large as 10′ × 20′ while producing an accurate sky flat that enables us to reach surface brightness limits of 27.5, 26, and 24.5 mag arcsec^{-2} in B_J, R, and I, respectively. The four selected regions are at medium to high latitude (Table 1) and contain isolated clouds <1° in extent, with a much smaller optically imaged subsection. Since an undetermined fraction of the background, in both the optical and 100 μm, is related to the cirrus, we had to make difference measurements between on and off the cloud, and sharp edges to the 100 μm cloud were selected for optical imaging.

TABLE 1. Some IR and Optical Properties of the Cirrus in Fields ir1-ir4

field	ir1	ir2	ir3	ir4
l_{II}, b_{II}	174°, −42°	235°, +37°	38°, +45°	72°, +25°
$\Delta S_{100\mu m}$/(MJy sr^{-1})[a]	11.44	3.55	5.86	4.70
$\Delta S_{60\mu m}/\Delta S_{100\mu m}$	0.22	0.21	0.17	0.19
A_V [b]	0.61	0.19	0.31	0.25
$\Delta S_{B_J}/\Delta S_{100\mu m}$	3.6×10^{-4}	1.1×10^{-3}	2.6×10^{-3}	—
B_J–R	1.7	1.2	1.0	—
R–I	—	<0.9	1.4	1.3

[a]brightness contrast within the optically imaged area
[b]estimated from $\Delta S_{100\mu m}$

Coadded *IRAS* maps were used to study the infrared (IR) properties of the cirrus. The far-IR surface brightness ($\Delta S_{100\mu m}$ in Table 1) is estimated by calculating the peak contrast in 100 μm brightness within the optically imaged region. The *IRAS* flux ratios (Table 1) indicate that the cirrus is heated by the ambient interstellar radiation field alone. A search for bright stars near our four fields has produced null results, supporting the above hypothesis. Using a standard gas-dust ratio and $T \approx 20$ K for the dust, we estimate the visual extinction A_V (Table

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1) through each cloud.

An inspection of the optical images reveals that the cirrus is detected in all bands and in each field. While the gross IR spatial features are reproduced in the optical, there are occasional areas of *excess* extended optical emission. These features are seen in more than one optical band and are not due to systematic error. All stars and galaxies were cleaned out from the optical images prior to smoothing and regridding to match the *IRAS* 100 μm images. A pixel-by-pixel comparison shows that the correlation is best between the B_J and 100 μm and worst for the I and 100 μm images. This evidence suggests the presence of a component *other than* scattered light in the diffuse radiation at longer optical wavelengths. For two clouds, the B_J to 100 μm brightness ratio (Table 1) is consistent with isotropic scattering of ambient starlight by optically thin cirrus (expected ratio: 3.3×10^{-3}). A third cloud shows a significant deficiency in blue flux, which can be explained by forward-scattering grains and an unfavorable scattering geometry (Witt 1977).

The spatial correlation between the different optical bands is better than the optical-IR correlation. The colors expected for optically thin scattering of disk light are B_J–R = 0.75 and R–I = 0.34. The most striking fact about the optical colors, B_J–R and R–I (Table 1), of the cirrus is that they cannot be explained by scattering alone. The observed colors are 0.5–1.0 mag redder than expected in both B_J–R and R–I. Furthermore, there is a lot of color variation from one part of the field to another, which is not correlated with the IR structure of the cloud, and cannot be accounted for by changing illumination. H_α emission from the cirrus has a negligible effect on its colors.

The R and I band excess seen in the cirrus is very similar to that in reflection nebulae (Witt and Schild 1986), in terms of both its magnitude and its nonuniform distribution. For reflection nebulae, this red excess is due to a broad luminescence feature in small hydrogenated amorphous carbon grains (Witt and Schild 1988). This red bump has also been seen in the spectra of dust clouds situated in milder radiation fields: the Red Rectangle (Schmidt, Cohen, and Margon 1980) and the dark cloud L1780 (Mattila 1979). The blue end of the ambient starlight spectrum contains enough energy to excite the luminescence in high-latitude cirrus, and so the R and I band emission seen may not be a surprise.

In a deep optical CCD survey of field galaxies, Tyson (1988) reported an extremely faint ($B_J \sim$ 29–30 mag arcsec^{-2}) blue (B_J–R ≤ 0) diffuse component. While a possible origin for this component may be unresolved clusters of very faint galaxies, scattered light from patchy high-latitude dust could not be ruled out at first. Our study of faint cirrus shows that its B_J–R color is too red (by $\geq$1 mag) to explain the diffuse radiation seen in Tyson's survey. The angular power spectrum of the cirrus, at levels below *IRAS* detectability and on scales smaller than *IRAS* resolution, can be studied using optical imaging. This study will determine whether spatial variations in the background produced by optical scattering and/or emission from the cirrus could provide a fundamental limiting surface brightness for faint extragalactic objects in the 30–31 B_J mag arcsec^{-2} range.

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