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Observations of the large-scale infrared emission from the Galactic plane region by the Diffuse Infrared Background Experiment

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1. INTRODUCTION

The Diffuse Infrared Background Experiment (DIRBE) on board NASA's Cosmic Background Explorer (COBE) satellite has surveyed the entire sky in 10 broad photometric bands covering the wavelength region from 1 to 240 μm, at an angular resolution of 0.7° (Boggess *et al.* 1992). The extensive spectral coverage of the DIRBE observations offers an unprecedented opportunity to undertake comprehensive large-scale studies of the content, structure, and energetics of the stellar and interstellar components of the Galaxy. Understanding the Galactic emission is not only a task of scientific value in its own right, but also a necessary step in the accurate extraction of faint cosmological emission from the DIRBE data.

The near-infrared ($\lambda < 5$ μm) bands, dominated by stellar emission, are used to decipher the stellar content and structure of the Galactic disk and bulge (§ 2 and § 4). Extinction in the near-infrared region of the spectrum is much lower than at visual wavelengths, but is high enough to influence the appearance of the Galaxy. The DIRBE near-infrared observations also provide information on the character and distribution of the absorbing dust grains (§ 2). Between 60 and 240 μm, the Galactic emission arises mainly from relatively cool ($T_D \sim 17 - 22$ K) dust heated by the general interstellar radiation field of the Galactic disk (§ 3). The far-infrared wavelengths allow investigation of the structure and energetics of the interstellar medium as traced by dust emission without the difficulties imposed by extinction (§ 3 and § 4).

2. NEAR-INFRARED (1.25 - 4.9 μm) OBSERVATIONS

The near-infrared (NIR) region of the spectrum is an excellent spectral window for the study of the stellar content of the Galaxy. The DIRBE NIR bands, corresponding roughly to the ground based J, K, L, and M photometric bands, probe this window with measurements of total intensity at wavelengths of 1.25, 2.2, 3.5, and 4.9 μm, and of linear polarization in the three shortest wavelength bands. At longer wavelengths, the diffuse Galactic light becomes dominated by the emission from dust associated with neutral atomic hydrogen gas, molecular gas, and H II regions (see § 3).

The DIRBE maps of the Galaxy at 1.25, 2.2, 3.5, and 4.9 μm show a smooth Galactic disk of starlight surrounding a boxy elliptical bulge (Weiland *et al.* 1993; § 4.1). In the longer wavelength bands, the stellar emission declines and the emission from dust in the interstellar medium (ISM) dominates the Galactic light. Extinction by dust in the ISM significantly influences the appearance of the Galaxy at 1.25 μm (e.g., a dust lane is visible across the bulge of the Galaxy), but it becomes less significant with increasing wavelength in accord with its known properties (e.g., Rieke & Lebofsky 1985).

The photometric data referred to in this section consist of observations spanning the six month interval from Dec 1989

to June 1990. The brightness contributed by interplanetary dust scattering and emission was removed using an empirical fitting function (Hauser 1993). The estimated inaccuracy in the removal of the interplanetary dust foreground is less than 2% and less than 5% of the median brightness of the inner Galaxy at 1.25 - 3.5 μm and at 4.9 μm, respectively. The errors in NIR colors due to the combined uncertainties of the absolute calibration and the zodiacal emission subtraction are estimated to be less than 10%. The results of this section have previously been reported by Arendt *et al.* (1993).

2.1. Extinction

Color-color diagrams of I(1.25 μm) / I(2.2 μm) vs. I(2.2 μm) / I(3.5 μm) and of I(2.2 μm) / I(3.5 μm) vs. I(3.5 μm) /I(4.9 μm) were generated by plotting the intensity ratios of each DIRBE pixel (~ 0.32° square) within various longitude ranges along the Galactic plane. For the inner Galaxy ($290° < \ell < 70°$), all three NIR colors are linearly correlated with one another, implying that one parameter (e.g., extinction) is sufficient to characterize the bulk of the observed color differences. The extent of these linear trends decreases towards the outer Galaxy and at higher latitudes. The range of colors is greatest for the I(1.25 μm) / I(2.2 μm) color and decreases with increasing wavelength.

For the inner Galaxy, the trends in these color-color diagrams are consistent with the assumption that the integrated Galactic light has a uniform intrinsic spectrum and is dominated by relatively distant emission which is seen through more local extinction. The slope of the reddening line is close to that implied by the Rieke & Lebofsky (1985) extinction law. The extended linear trend seen in the inner Galaxy cannot result from a uniform distribution of stars and dust. With a uniform distribution, the emission will be dominated by nearby stars with low amounts of reddening, and the reddening in different bands will not be linearly correlated as observed in the color-color diagrams.

The color-color diagrams of Cygnus and other star-forming regions cannot be explained by extinction effects alone. The Cygnus Region ($\ell = 70° - 90°$) shows a greater range of colors than suggested by the general trend of decreasing extinction with increasing longitude, and in the shorter wavelengths the trend has a significantly steeper slope. Possible explanations for this are discussed below (§ 2.4).

Assuming that the Galaxy can be characterized by a single intrinsic I(1.25 μm) / I(2.2 μm) color, the observed colors and reddening law can be used to construct a map of dust optical depth at 1.25 μm, $\tau_{1.25}$. Toward the inner Galaxy and bulge, features in this map are anti-correlated with the intensity at 1.25 μm. The $\tau_{1.25}$ map has been compared with the optical depth map at 240 μm constructed from the dust emission in the 140 and 240 μm DIRBE bands (Sodroski *et al.* 1993; § 3.2). Where $\tau_{1.25} \leq 1.0$, it is well correlated with the DIRBE 240 μm optical depth, implying that where the line of sight is optically thin at 1.25 μm, the same dust is observed in both absorption and emission. The linear correlation of $\tau_{1.25}$ and τ_{240} breaks down along the Galactic plane, where $\tau_{1.25} > 1$ and $\tau_{240} << 1$, because the dust path length sampled at 240 μm is longer than that at 1.25 μm. Either the 1.25 μm or the 240 μm maps can be used quite successfully to remove the effect of extinction from the DIRBE maps at Galactic latitudes $|b| > 3°$.

2.2 Polarization

DIRBE polarimetry shows a "knot" of polarization 3° north ($\ell = 0°$, b = 3°) of the Galactic Center, coincident with a region of higher than average optical depth at 1.25 μm (Berriman *et al.* 1993; Weiland *et al.* 1993). This feature is produced by the Barnard 78 complex (Lynds 1962), a group of small, very dark clouds that lie along the line of sight to the Galactic bulge, and are easily seen on wide-angle photographs. The degree of polarization, P, is strongly wavelength dependent, in accord with the interstellar polarization law (Martin & Whittet 1990): P = 1.8% at 1.25 μm, 1.4% at 2.2 μm, and 0.6% at 3.5 μm. This implies that extinction of starlight by the dark material gives rise to the polarization. The polarization and NIR colors of the Barnard 78 complex demonstrate that dust extinction is responsible for the "peanut" appearance of the northern Galactic bulge.

2.3 Intrinsic colors of stellar populations

The median colors of high latitude regions ($10° < |b| < 15°$) where the extinction appears to be low were used to define the nominal colors of Galactic stellar populations. For the bulge population such regions were at $350° < \ell < 10°$. Regions outside this longitude range were used to determine the nominal colors of the disk population. The extrapolation of the reddening lines from high extinction regions (i.e., lower latitudes) passes through these median colors, supporting their identification as the nominal source population colors.

To characterize the integrated colors of the stellar populations, the nominal observed colors were compared with those of isolated bright stellar sources that were detected by DIRBE. The unreddened Galactic light from both bulge and disk at 1.25 - 4.9 μm exhibits colors similar to those of late K and M giants. The bulge stars appear to have I(2.2 μm) / I(3.5 μm) color ≤ 3% bluer than the disk stars, which is in accord with the finding that the bulge stars are ~ 400 K hotter than their disk counterparts (Terndrup, Frogel, & Whitford 1991). Difficulty in accurately determining the limit of $\tau \rightarrow 0$ prevents clear distinction between the I(1.25 μm) / I(2.2 μm) colors of the bulge and disk populations.

2.4 Evidence for NIR emission from hot dust

The shorter-wavelength (1.25 - 3.5 μm) color-color diagrams of star-forming regions that are not superimposed on the brightest regions of the Galactic disk (e.g., the Cygnus, Carina and ρ Oph regions, Orion A and B, and the Rosette Nebula) show a weaker correlation of colors with a steeper slope than those of the Galactic disk and bulge. These star-forming regions are also visible above the background confusion in the 3.5 and 4.9 μm bands, and correlate well with the bright sources seen in the 12 and 25 μm images. The lack of emission at 1.25 and 2.2 μm suggests that the near-IR radiation of star-forming regions has a color temperature of ~ 900 K. The color-color diagrams for the Cygnus region can result from mixing the typical Galactic stellar emission with such a second component. The stellar emission of the Galaxy dominates at 1.25 and 2.2 μm, while at 3.5 and 4.9 μm the cooler emission is brighter. The longer-wavelength (2.2 - 4.9 μm) color-color diagrams for star-forming regions can be interpreted in a similar fashion, except that here the color temperature of the second component appears to be ~ 600 K.

The 900 K color temperature may arise from equilibrium grains that lie very close to the stellar heating sources, or from transiently heated grains which can be more widely distributed in the star-forming regions. The 600 K color temperature at longer wavelengths would reflect the increasingly important contribution of cooler dust. It is also possible that the apparent 900 K color temperature arises from very heavily reddened ($\tau_{1.25} \geq 5$, or $A_v \geq 19$) stars of spectral type A or earlier. Such stars must be intrinsically very luminous if they are to provide the 3.5 and 4.9 μm emission of star-forming regions despite high extinction. More detailed analysis of specific star-forming regions is necessary for a thorough resolution of this phenomenon.

3. FAR-INFRARED (60 - 240 μm) OBSERVATIONS

The Galactic large-scale far-infrared (FIR) emission, originally observed by Hoffman and Frederick (1969), arises primarily from radiatively heated dust. The details concerning the physical properties of the dust and the nature of the stellar populations that heat it within each of the gas phases of the ISM are still a subject of intense studies (see review by Cox & Mezger 1989). A major advancement of the field was made possible by the successful mission of the Infrared Astronomical Satellite (IRAS; Neugebauer *et al.* 1984), which provided complete coverage of the entire sky at wavelengths of 12, 25, 60, and 100 μm, with a much greater sensitivity than the earlier balloon experiments. As a result, several independent IRAS studies of the Galactic large-scale 60 and 100 μm emission (Sodroski *et al.* 1986, 1987, 1989; Bloemen, Deul, & Thaddeus 1990; and references therein) placed important constraints on the physical conditions within the molecular (H_2), neutral atomic (H I), and extended low-density ionized (H II) gas phases of the interstellar medium, and the distribution of FIR luminosity among these gas phase components.

However, major issues are still unresolved, such as the exact stellar populations that heat the dust that is responsible for the emission, the equilibrium dust temperatures of large dust grains, the dust-to-gas mass ratios within the gas phases of the

ISM, and the prevalence of very cold and of stochastically heated dust. One reason for this situation is that IRAS, with its limited spectral coverage, may not be sensitive to a cold dust component that may constitute a large fraction of the total dust mass in the ISM. In addition, because there is strong evidence (Sodroski *et al.* 1989, and references therein) that there is a significant contribution to the Galactic emission at 60 μm from very small (< 10 Å), transiently heated grains, equilibrium dust temperature estimates from the IRAS 60 to 100 μm intensity ratios are biased toward high values, which also causes underestimation of dust column density.

The DIRBE instrument, in spite of its limited spatial resolution (~ 0.7°), has an extensive spectral coverage and therefore effectively samples most of the dust components of the ISM. At present, we restrict our analysis to the DIRBE 140 and 240 μm observations since the 60 and 100 μm detectors are believed to have a nonlinear responsivity which has not yet been fully characterized. The DIRBE 140 and 240 μm observations are combined with radio observations that trace the H_2, H I, and H II gas phases to derive the average large-scale physical conditions in the interstellar medium, and the large-scale physical conditions within each of the three gas phases. Because the DIRBE 140 and 240 μm observations primarily sample the interstellar medium's large dust grain component which attains an equilibrium temperature in the ambient radiation field, the results of our analysis can be combined with the results of the IRAS studies to arrive at a more complete interpretation of the Galactic large-scale FIR emission. The results of this analysis have also been reported by Sodroski *et al.* (1993).

3.1 Data sets

The 140 and 240 μm observations used here are from data averaged over 10 months of cryogenic operation. Preliminary absolute calibration of the 140 and 240 μm bands is based on observations of Jupiter and has an estimated uncertainty of ~ 10%. No attempt has been made to remove the zodiacal emission component from the observations. Since this analysis is primarily restricted to the region $|b| < 1.25°$, where the zodiacal component is everywhere estimated to be less than 10% of the observed 140 μm emission and less than 5% of the observed 240 μm emission, the presence of zodiacal emission will not lead to large uncertainties in the derived results.

The radio data used in this section comprise the Galactic plane surveys of ^{12}CO from the Goddard Institute for Space Studies (Dame *et al.* 1987), the Berkeley/Hat Creek (Weaver and Williams 1973, 1974*a*, *b*), Maryland/Parkes (Kerr *et al.* 1986), and NRAO (Burton & Liszt 1983) Galactic plane surveys of neutral atomic hydrogen, and the Haynes, Caswell, & Simons (1978) Galactic plane survey of the 5 GHz radio-continuum.

3.2 Derived physical conditions assuming a single temperature along each line of sight

Galactic plane region maps of the 140 μm, 240 μm, and 5 GHz radio continuum emission, and of the velocity-integrated ^{12}CO and H I emission at various angular resolutions were derived in order to facilitate comparison of the radio data with the DIRBE data. These maps were used to derive maps of the dust temperature, T_d, optical depth at 240 μm, τ_{240}, and the total FIR brightness over all FIR wavelengths ($\lambda > 40$ μm), I_{FIR}, by assuming an isothermal dust distribution along each line of sight, and a λ^{-2} emissivity law (see Sodroski *et al.*(1987) for details of this type of analysis). Maps of the ^{12}CO and H I emission were used to obtain maps of $N(H_2)$ and N(H I), the line-of-sight H_2 and H I column densities, respectively, by adopting a value of 2.0×10^{20} molecules cm^{-2} K^{-1} km^{-1} s for the ratio of H_2 column density to ^{12}CO intensity (Lebrun *et al.* 1983). The maps of τ_{240}, I_{FIR}, and a map of total H-atom column density, N_H (= N(H I) + 2 $N(H_2)$), were then used to obtain maps of the gas-to-dust mass ratio, Z_G, and $L_{IR}{}^{H}$, the FIR luminosity per hydrogen mass, by adopting a dust mass absorption coefficient at 240 μm of 7.2 cm^2 g^{-1} (Hauser *et al.* 1984).

The 240 μm optical depth has a maximum value of ~ 0.02. The corresponding optical depth at 140 μm is ~ 0.06. This implies that, averaged over the 0.7° DIRBE beam, the Galaxy is optically thin at these wavelengths. The total FIR brightness at b = 0° decreases by more than an order of magnitude from the inner ($270° < \ell < 90°$) to the outer ($90° < \ell < 270°$) Galaxy.

Longitude profiles of the dust temperature, gas-to-dust mass ratio, and FIR luminosity per hydrogen mass at $b = 0°$ were derived. The profiles represent the mean properties within the latitude interval $|b| < 0.75°$. The dust temperature has a mean

value over all longitudes of ~ 19 K, and decreases by ~ 20% from the inner to the outer Galaxy. We have also examined the latitude distribution of dust temperature from data averaged over 12 longitude bins. The latitude distribution of dust temperature displays a general trend of decreasing temperature with increasing latitude for the inner Galaxy, and increasing temperature with increasing latitude for the outer Galaxy. These results suggest that the dust temperature in the Galactic disk decreases significantly with increasing galactocentric distance.

The gas-to-dust mass ratio profile has a mean value of $\langle Z_G \rangle \sim 160$, a value consistent within the uncertainties with the local canonical value of ~ 100. The value of Z_G increases by ~ 35% from the inner to the outer Galaxy. Assuming that the gas-to-dust mass ratio in the Galactic disk varies inversely as the heavy-element abundance, the derived increase in Z_G from the inner to the outer Galaxy is expected based on the inferred Galactic metallicity gradient (Panagia & Tosi 1981). However, because of the probable existence of dust components at widely different temperatures (Sodroski *et al.* 1989) and the possible existence of a very cold dust component which contributes only a small fraction of the total flux in the DIRBE 140 and 240 μm bands (see, for example, Wright *et al.*1991), the assumption of a single dust temperature along each line of sight may lead to large errors in derived dust mass column density. Therefore, the derived increase in Z_G from the inner to the outer Galaxy may not be real.

The FIR luminosity per hydrogen mass profile has a mean value in the inner Galaxy of ~ 3 $L_\odot M_\odot^{-1}$, and decreases by a factor of ~ 4 from the inner to the outer Galaxy. The derived decreases from the inner to the outer Galaxy in the dust temperature and FIR luminosity per hydrogen mass profiles suggest that the ambient radiation field which heats the large dust grains in the interstellar medium decreases rapidly with increasing galactocentric distance.

Within a few degrees of longitude of the Galactic Center, the gas-to-dust mass ratio reverses its general trend of decreasing Z_G toward the inner Galaxy and increases by a factor of ~ 2 - 3 above the inner Galaxy value. The FIR luminosity per hydrogen mass also reverses its general trend and decreases by a similar factor below the inner Galaxy value. One possible explanation of these results is that the ratio of H_2 column density to ^{12}CO intensity is significantly lower in the central region of the Galaxy than in the Galactic disk (Blitz *et al.* 1985), in which case the column density of molecular gas along lines of sight near the Galactic center has been overestimated. Another possible explanation is that there is a significant deficiency of dust in the central region of the Galaxy (galactocentric distance < 500 pc) relative to the Galactic disk.

3.3 Physical conditions within the individual gas phases of the ISM

The large-scale physical conditions within the three most massive gas phases (H_2, H I, and H II) of the ISM have been inferred by applying the linear decomposition method of Sodroski *et al.* (1989) to the full-resolution 140 and 240 μm data within the region $300° < \ell < 40°$, $|b| < 1.25°$. For the H I gas phase, the derived dust temperature and FIR luminosity per hydrogen mass profiles at b = 0° each decrease with increasing longitude in a manner consistent with that expected for dust heated by the general interstellar radiation field. A comparison of the results with the results of a similar analysis of the IRAS 60 and 100 μm data (Sodroski *et al.* 1989) shows that the relative contribution to the FIR intensity from the molecular component increases with increasing wavelength, whereas that from the ionized component decreases with increasing wavelength, consistent with the generally accepted view that dust associated with ionized gas has a higher equilibrium temperature than dust associated with molecular gas. The FIR luminosity per hydrogen mass profiles for the H I gas phase from the two decompositions are in close agreement. However, the dust temperature profile for the H I gas phase from the IRAS decomposition shows no significant variation with longitude. These results imply that the IRAS 60 and 100 μm bands do not accurately determine the equilibrium temperature of the bulk of the dust sampled by DIRBE. The likely explanation for this discrepancy is the presence within the diffuse H I gas of very small (< 10 Å) dust grains that are stochastically heated by the general interstellar radiation field, and which contribute significantly to the Galactic emission at 60 μm (Sodroski *et al.* 1989).

From the mean FIR luminosity per hydrogen mass for each of the three gas phases, and previous estimates of the total mass of each gas phase, the total FIR luminosity for each gas phase can be inferred. The total FIR luminosity ($\lambda > 40$ μm) of the Galactic disk is ~ 1.1×10^{10} $L_\odot$, with 70%, 20%, and 10% from dust associated with neutral atomic hydrogen clouds, molecular clouds, and extended low-density H II regions, respectively. These results are in close agreement with the results of the IRAS analyses of the Galactic plane (Sodroski *et al.* 1986, 1987, 1989; Bloemen, Deul, & Thaddeus 1990; and references

therein). It has been estimated (Sodroski *et al.* 1989) that mid-infrared (10 μm < λ < 40 μm) emission from very small, stochastically heated grains consitutes about 30% - 50% of the total Galactic infrared (λ > 10 μm) luminosity. Therefore, the total infrared luminosity of the Galactic disk is ~ (1.6 - 2.2) x 10^{10} $L_{\odot}$, which is in close agreement with the estimate for the total Galactic infrared luminosity from the Wright *et al.* (1991) analysis of the Galactic large-scale infrared emission using COBE FIRAS data.

4. GALACTIC STRUCTURE

4.1 The shape of the Galactic bulge

The Galactic bulge is clearly visible in the four DIRBE bands at wavelengths ≤ 4.9 μm. Extinction by dust leads to a somewhat different appearance in each of the DIRBE bands. However, by using the reddening law to derive the extinction, or by using the extinction inferred from the 140 - 240 μm emission, the influences of extinction on the appearance of the bulge can be removed (see § 2.1). Once this is done, the Galactic bulge appears intrinsically very similar at wavelengths from 1.25 to 4.9 μm. Weiland *et al.* (1993) report that the DIRBE NIR data reveal a boxy-ellipsoidal bulge with an exponentially falling surface brightness along its minor axis (normal to the plane of the Galaxy), with an angular scale-length of 2.7°. After correction for extinction, the data also show systematic asymmetries, which in general conform to the signatures of a barlike distribution that were described by Blitz & Spergel (1991) in their analysis of NIR balloon-borne observations (Matsumoto *et al.* 1982). However, there is no significant inclination of the major axis of the bar with respect to the plane of the Galaxy, which is contrary to the 3° - 7° inclination which Blitz & Spergel (1991) had inferred.

4.2 The warp of the Galactic disk

It has long been known that at large galactocentric distances the neutral atomic hydrogen (H I) gas layer is warped (Burke 1957; Kerr 1957). It rises above the nominal plane in the direction of ℓ ~ 90° and falls below it at ℓ ~ 270° (Burton & Deul 1987). Molecular clouds and cool (~ 20 K) dust appear to exhibit the same behavior (Wouterloot *et al.* 1990; Sodroski *et al.* 1987). Evidence for a warping of the Population I stellar component has been obtained through studies of Cepheid, OB-type, and WR stars, and studies of open clusters and supernova remnants (see, for example, Miyamoto *et al.* 1991; Pandey *et al.* 1990). Djorgovski & Sosin (1989) have derived the latitude distribution of old stellar tracers such as AGB and post-AGB stars in the IRAS Point Source Catalog at 12 and 25 μm, and find evidence for a warp similar to that of the neutral atomic hydrogen gas layer.

A comparison of DIRBE observations of the Galactic plane region with neutral atomic hydrogen (H I) surveys can be used to investigate the signature of the warp over a wide range of IR wavelengths. Freudenreich *et al.* (1993) derive and compare the distributions of the latitude centroids of the Galactic emission at all DIRBE wavelengths, and of the Galactic H I emission, to search for evidence of the warp in the interstellar dust layer and stellar component of the Galaxy.

4.2.1 Method

Latitudinal asymmetries in surface brightness were calculated from equal-area cylindrical projection maps of the Galactic plane region, $|b|$ < 7°, at 1.25, 2.2, 4.9, 100, and 240 μm. The bright resolved stars in the four shortest wavelength bands were removed using an iterative filtering algorithm. The contribution of the zodiacal light at wavelengths ≤ 100 μm was removed by applying the empirical model of Hauser (1993). For this preliminary investigation, the purpose of which is to search for evidence for the warp in the DIRBE data, the centroid was taken as the mean latitude, weighted by the surface brightness, over the latitude interval $|b|$ < 7°. Limiting the integration range to $|b|$ < 7° avoids the most prominent local sources, such as the clouds in the Taurus, Orion, and Ophiuchus regions.

4.2.2 The far-infrared: H I and dust

At 100 and 240 μm, the DIRBE primarily samples the thermal emission of cool dust. The distributions of the latitude centroids of the 100 μm, 240 μm, and velocity-integrated H I emission (§ 3) are very similar, showing that there exists a strong correlation between gas and dust. The same analysis was applied to a map of the optical depth at 240 μm (§ 3), demonstrating that the displacement of the 240 μm latitude centroid from $b = 0°$ is primarily due to variations in dust column density rather than dust emissivity. These results imply that the Galactic dust layer and neutral atomic hydrogen layer are similarly warped.

4.2.3 The near-infrared: stars

DIRBE's near-infrared photometry in the Galactic plane is dominated by older stars of the disk, in particular K and M giants. Evidence for the warp is present at all of the near-infrared wavelengths. The peak-to-peak amplitude increases with increasing wavelength: 0.35°, 0.65°, 0.9°, 1.0°, going from 1.25 to 4.9 μm. This is consistent with a stellar disk that curves away from b = 0° beyond the solar circle. The longer the wavelength, the smaller the extinction, and the greater the contribution of distant and more highly-displaced stars to the surface brightness.

5. SUMMARY

Preliminary analysis of the DIRBE observations of the Galactic plane region emission at wavelengths from 1 to 240 μm has revealed many new and exciting results on the stellar and interstellar components of the Galactic disk and bulge. The major results can be summarized as follows:

1. The integrated Galactic starlight has NIR colors similar to those of K and M giants. Differences between the colors of the disk and bulge populations are small.

2. Extinction strongly influences the appearance of the disk and bulge at wavelengths shortward of 2.2 μm. The variation of extinction with wavelength is similar to the expected variation for the Rieke & Lebofsky (1985) reddening law.

3. Emission from hot dust associated with active star-forming regions appears to contribute significantly to the emission in the 3.5 μm and 4.9 μm DIRBE bands.

4. Most (≥ 90%) of the Galactic FIR ($\lambda > 40$ μm) luminosity arises from cold ($T_d \sim 17 - 24$ K) dust associated with diffuse H I clouds and molecular gas, in close agreement with the results of previous analyses of the Galactic FIR emission using IRAS data.

5. The equilibrium dust temperature and FIR luminosity per hydrogen mass for the diffuse H I gas increase significantly from the outer to the inner Galaxy, consistent with a model in which dust associated with this gas phase is heated by the Galactic interstellar radiation field.

6. Within the central region of the Galaxy (galactocentric distance < 500 pc), the ratio of H_2 column density to ^{12}CO intensity is significantly lower than in the Galactic disk and/or there is a significant deficiency of dust relative to the Galactic disk.

7. The stellar emission of the Galactic bulge shows systematic asymmetries which in general conform to the signatures of a barlike distribution. There is no evidence for a significant inclination of the major axis with respect to the plane of the Galaxy.

8. A comparison of DIRBE observations of the FIR emission from the Galactic plane region with neutral atomic hydrogen surveys implies that the Galactic dust layer and neutral atomic hydrogen layer are similarly warped. Evidence for the warp is present at all of the NIR wavelengths.

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