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THE LARGE SCALE GAS AND DUST DISTRIBUTION IN THE GALAXY: IMPLICATIONS FOR STAR FORMATION

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ABSTRACT

We present IRAS observations of the diffuse infrared (IR) emission from the galactic plane at wavelengths of 60 and 100 μm and derive the total far infrared intensity and its longitudinal variation in the disk. Using available CO, 5 GHz radio-continuum, and HI data, we derive the IR luminosity per hydrogen mass, and the infrared excess (IRE) ratio in the Galaxy.

We linearly decompose the longitudinal profiles of the 60 and 100 μm emission into three components that are associated with the molecular (H_2), neutral (HI), and ionized (HII) phases in the interstellar medium (ISM), and derive the relevant dust properties (ie. temperature, IR luminosity per hydrogen mass, total IR luminosity) in each phase. Implications of our findings for various models of the diffuse IR emission and for star formation in the galactic disk are discussed.

I MORPHOLOGY OF THE FIR EMISSION FROM THE GALACTIC PLANE

Figures l(a) and l(b) show the longitudinal profiles of the observed 60 and 100 μm galactic plane emission, from which the contribution of the zodiacal emission was subtracted using the empirical model of Boulanger (1986). The profiles represent average intensities over the latitude interval $|b| < 0.25$ in longitude increments of 0.5 . As seen in Figure 1, the far infrared (FIR) emission originates primarily from within the solar circle. Most of the discrete sources are in the direction of, and likely associated with, known HII region/molecular cloud complexes. Figure l(c) is a profile of the total IR intensity, integrated over all wavelengths, assuming the dust at a given longitude emits at the corresponding line-of-sight temperature, with an emissivity index of n = 2. The mean value of the total IR intensity in $W m^{-2} sr^{-1}$ is 4×10^{-5} over the longitude range $1 = 270^{\circ}$ to 90° and 2×10^{-5} over the entire Galaxy (Note: The 0.5 position error in the original Zodiacal History File data has been corrected).

II COMPARISON WITH CO, HI, AND 5 GHZ SURVEYS

i) Correlation of Mean Intensity Profiles

We have compared Figure l(c) with longitudinal profiles of the velocity-integrated ^{12}CO and HI emission, and 5 GHz radio-continuum emission from the galactic plane, all profiles representing the mean intensity over -0.25 to 0.25 in latitude. The data used to derive the profiles comprise the galactic plane surveys of ^{12}CO from the Goddard Institute of Space Studies (GISS), the
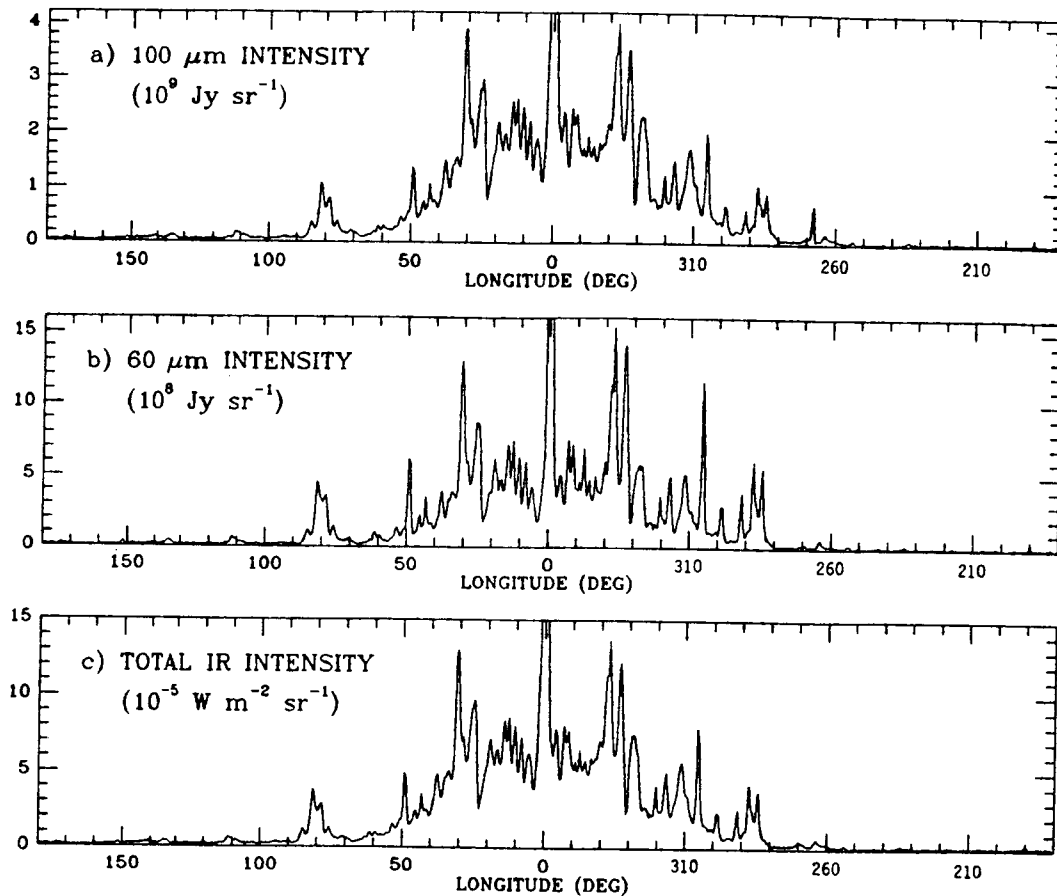
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Figure 1. (a) and (b) Longitudinal profiles of the galactic plane emission as observed by IRAS and corrected for the zodiacal emission. (c) Profile of the total IR intensity.

Berkeley (Weaver and Williams 1974) and Parkes (Kerr et al 1986) galactic plane surveys of neutral atomic hydrogen, and the Haynes–Caswell (1979) galactic plane survey of the 5 GHz radio-continuum. The longitudinal variation of the total IR intensity closely correlates with both the CO and 5 GHz continuum emission, which originate from regions associated with the younger galactic populations (i.e. molecular cloud complexes, extended low density (ELD) HII regions), primarily located in the vicinity of spiral arms.

ii) The Infrared Luminosity Per Hydrogen Mass, and
Infrared Excess (IRE) Ratio

The total hydrogen column density along a given line-of-sight can be derived from the velocity-integrated ^{12}CO and HI intensities. It can be used together with the total IR intensity to calculate the infrared luminosity per hydrogen mass, L_{IR}^{H}. The longitudinal profile of L_{IR}^{H} is plotted in Figure 2(a) in units of $L_\odot/M_\odot$. Many of the peak values shown in the figure lie in the directions of spiral arms. The mean value of L_{IR}^{H} over the entire range of longitudes is ~ 3 $L_\odot/M_\odot$, a value similar to that in clouds heated only by the interstellar radiation field (Weiland et al 1986).

The infrared excess ratio, defined as the IR-to-Lyα luminosity ratio, is plotted in Figure 2(b). The IRE ratio is relatively constant with longitude,
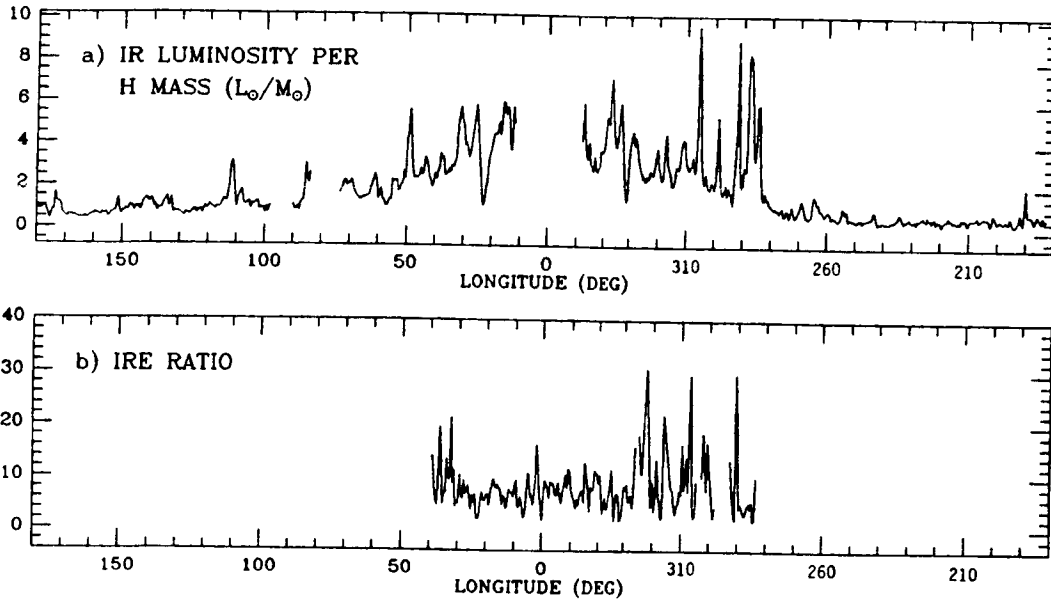
Figure 2. (a) Galactic longitude profile of the infrared luminosity per hydrogen mass. The mean value is ~ 3 $L_\odot/M_\odot$. (b) The IRE ratio.

suggesting that the stellar initial mass function (IMF) is largely unchanged throughout the inner Galaxy. This observed behavior contradicts the claim of Gispert et al (1982) that there exists a marked increase of the IMF with decreasing galactocentric radius, and, as must follow, that the inner galaxy is deficient in producing OB stars relative to the solar vicinity. The mean value of IRE is ~ 6 , and implies that known (instead of embedded) OB stars can provide a large fraction of the radiation needed to heat the dust that is responsible for the diffuse IR emission.

III A NEW APPROACH: A LINEAR DECOMPOSITION OF THE IR INTENSITY INTO ITS GAS PHASE CONTRIBUTIONS

We have linearly decomposed the IRAS data into three emission components associated with the most massive gas phases (H_2 , HI, and HII) in the ISM as follows. We assumed a constant gas-to-dust mass ratio and grain temperature in each of the three phases. Then, at every longitude 1, the observed intensity in an IRAS band i(=1,2) is given by the linear combination of the dust emissivity per unit gas mass, e_{ij} , in each gas component j(=1,2,3), multiplied by the column density of that component. In order to obtain the column density of the ionized gas we assumed a gas density of 10 cm^{-3} in the ELD HII regions. The best fit to the flux in each band was found by adjusting the e_{ij}'s. A statistical analysis of our decomposition algorithm has confirmed that the parameters of the three components are linearly independent. The resulting e_{ij}'s were used together with an adopted emissivity index of n = 2 to obtain the dust temperature, the total IR intensity, the IR luminosity per hydrogen mass, and the gas-to-dust mass ratio in each gas phase component. Our results are summarized in Table 1.

TABLE 1: DERIVED DUST QUANTITIES IN THE VARIOUS ISM PHASES

Gas Phase	Dust Temp (K)	Gas-to-Dust Mass Ratio	FIR Luminosity per H Mass ($L_\odot/M_\odot$)	%Contribution 60 μm	%Contribution 100 μm	%Contribution Total FIR	Total Mass ($M_\odot$)	Total Luminosity ($L_\odot$)
H_2	20	190	2.3	20	40	40	2.0×10^9 [a]	4.6×10^9
HI	24	270	2.8	30	33	30	2.6×10^9 [b]	7.3×10^9
HII	31	190	28.0	50	27	30	3.7×10^7 [c]	1.0×10^9
Mass-averaged Values		200	3.8					

References: (a)Cohen (1978); (b)Baker and Burton (1975); (c)Mezger (1978)

SUMMARY

We have calculated the contribution of the H_2 , HI, and HII regions to the galactic 60 and 100 μm emission. The major results of our calculations are listed in Table 1 and can be summarized as follows.

1) The molecular, neutral atomic, and ionized gas components contribute about equally to the total IR intensity. The total IR luminosity of the Galaxy is about 1.3×10^{10} $L_\odot$, with 35, 55, and 10 percent from H_2 , HI, and HII regions respectively.

2) The IR luminosity per hydrogen mass is ~ 2 - 3 for the H2 and HI components, comparable to that of interstellar clouds heated by the interstellar radiation field alone. Therefore, molecular and HI clouds typically do not seem to have highly luminous, embedded heating sources.

3) The IRE ratio is ~ 6, implying that known OB stars can provide a large fraction of the energy needed to heat the dust. Its constancy with longitude implies that the stellar IMF does not vary significantly in the disk.

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