Far Infrared Luminosity Functions of Normal Galaxies

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Abstract : We construct a volume limited sample of 443 optically selected nearby galaxies from the Zwicky catalog to study far infrared luminosity functions. Schechter function fits and integrated luminosity densities are calculated. Comparing the resulting infrared spectrum with the infrared spectrum for interstellar matter in the solar neighborhood, we find most of the infrared emission is due to dust heated by the interstellar radiation field, except at 60μm emission where star forming regions contribute significantly.

We constructed a volume limited sample ($v<1400 kms^{-1}$) of 443 nearby galaxies from the Zwicky catalog (Huchra *et al.* 1983) to study far infrared luminosity functions of optically selected galaxies. The infrared data are obtained from the *IRAS Point Source Catalog II* and ADDSCAN processing. Detailed descriptions of the selection and processing of the sample are presented in Isobe and Feigelson (1989). Since many of the galaxies are not detected in the infrared, the non-parametric survival analysis Kaplan-Meier estimator (Feigelson and Nelson 1985; Isobe, Feigelson, and Nelson 1986) is used to calculate normalized integrated luminosity functions. The luminosity functions based on the volume limited sample show good agreement with those based on magnitude limited samples. Since survival analysis can be directly applied to the volume limited sample, the luminosity function based on the volume limited sample is the better choice for the samples selected in other wavebands.

The luminosity functions at 12, 25, 60, and 100 μm Kaplan-Meier estimator are shown in Fig. 1. $H_0 = 75 km\ s^{-1}\ Mpc^{-1}$ is assumed throughout. Schechter functions (Schechter 1976) are fitted to these luminosity functions to find luminosity density per Mpc^3. Since many galaxies are not detected, a simple sum of detected galaxies does not give total luminosities. Results are listed in Table 1. The fourth to sixth columns list the Schechter function parameters for

$$\phi\, d(L/L^*) = \phi^* (L/L^*)^{\alpha+1} \exp(-L/L^*)\, d(L/L^*), \quad (1)$$

Table 1: Mean Luminosities and Parameters of Schechter Functions of Four IRAS Bands

Band	Upper Limits	Mean (erg s^{-1} Hz^{-1})	α	log L*	φ*	Total Luminosity Density (erg s^{-1} Hz^{-1} Mpc^{-3})
1	323	28.14±0.12	-1.67	29.0	1.7×10^{-1}	3.3×10^{27}
2	303	28.37±0.09	-1.69	29.2	1.8×10^{-1}	5.1×10^{27}
3	121	29.46±0.04	-1.59	30.1	1.5×10^{-1}	4.7×10^{28}
4	118	29.88±0.04	-1.41	30.4	1.2×10^{-1}	1.3×10^{29}

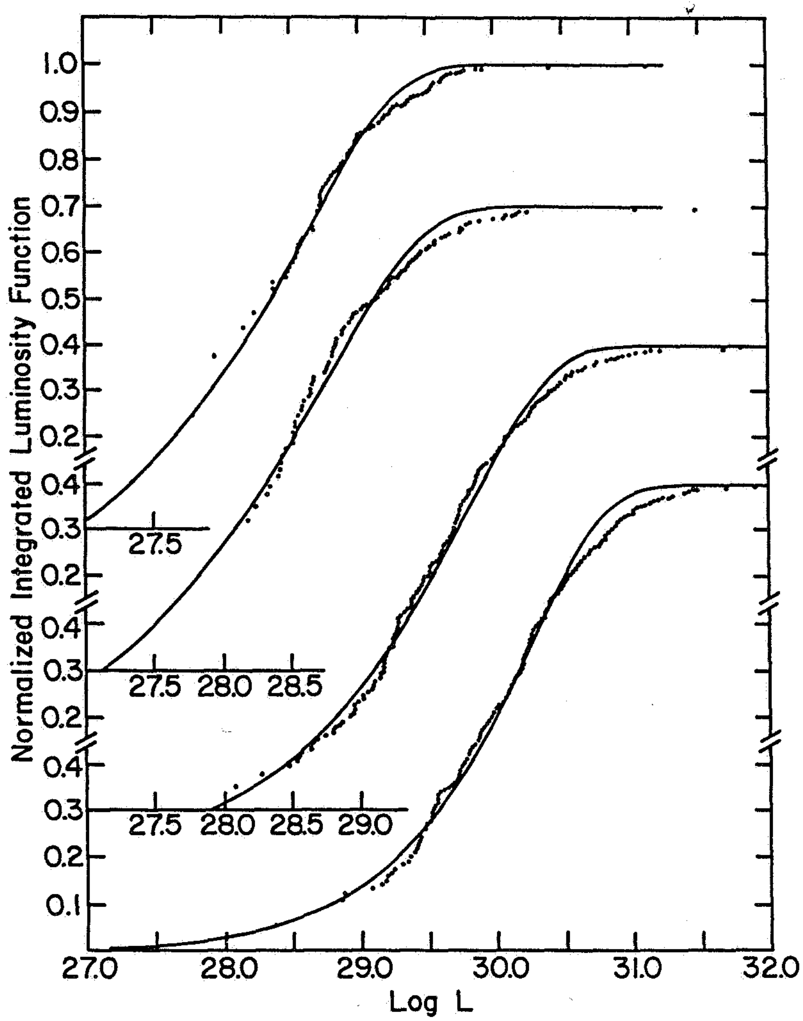

Figure 1 :
The luminosity functions for 12, 25, 60, and 100 µm from top to bottom. The fitted lines are Schechter functions.

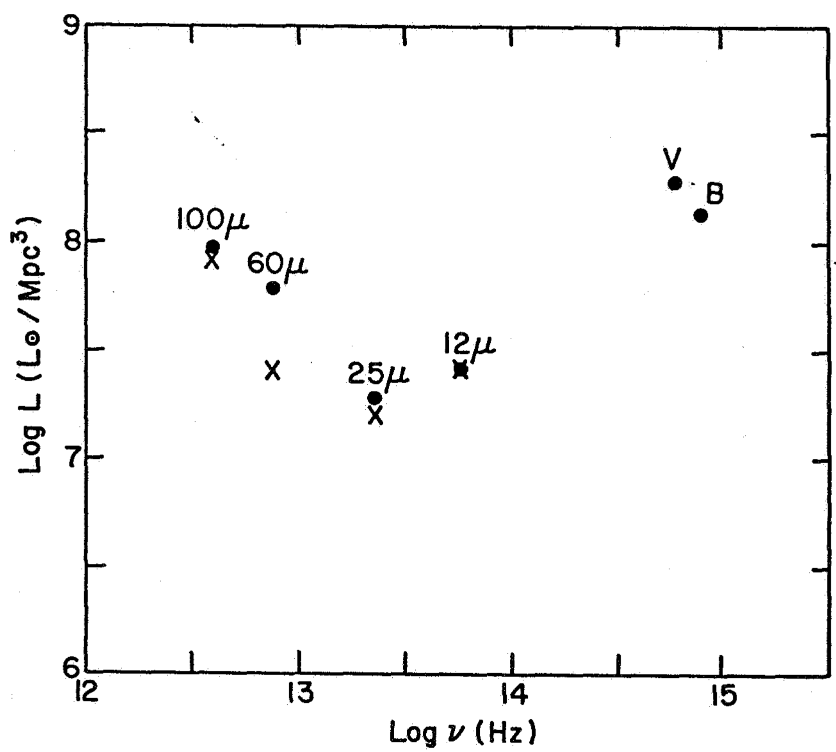

Figure 2 :
The luminosity densities per Mpc^3 in solar luminosity units. The filled circles are obtained from Table 1, Felten (1977; V band) and Kirshner *et al.* (1983; B band), respectively.The crosses are obtained from Boulanger and Pérault (1988) normalized at 12µm.

where ϕ^* is in number of galaxies per Mpc^3, L^* is in erg s^{-1} Hz^{-1}. The last column lists the total luminosity density of optical galaxies in the local Universe of the band in erg s^{-1} Hz^{-1} Mpc^{-3}. Note, bands 1 and 2 have very low detection rates (~30%) and if survival analysis is not used, computations of luminosity functions are impossible. We find the mean L^* and integrated luminosities increase a factor of ~40 between 12 and 100μm monotonically with wavelength. The slope α is always steeper than seen at optical wavelengths where $\alpha \approx -1.25$.

The luminosity densities per Mpc^{-3} in Table 1 can be seen as a spectrum of a 'typical' galaxy. Boulanger and Pérault (1988; hereafter BP) present the infrared emission originating in the solar neighborhood based on IRAS data, and present the infrared spectrum of emission normalized per hydrogen atom. If we assume that a typical galaxy has a similar environment, their values can be used as a reference spectrum which represents the emission of dust heated by the interstellar radiation field. Since 12μm emission is almost certainly due to very small grains (e.g. polycyclic aromatic hydrocarbon; Léger and Puget 1984), we normalize the 12μm point of BP to that of our typical galaxy in Fig. 2 ($L_{12\mu m}=2.6 \times 10^7 L_\odot$). They agree very well with the solar neighborhood spectrum, except at 60μm. Our 60μm emission is 2.5 times higher than of BP.

Since some galaxies are not detected both at $L_{100\mu m}$ and $L_{60\mu m}$, we cannot compute the distribution of $L_{100\mu m}/L_{60\mu m}$ color correctly. Nontheless we attempt to compute the luminosity density of galaxies with $L_{100\mu m}/L_{60\mu m}<2.5$ which are supposed to be dominated by star formation. The contribution from these galaxies in our sample is $2.1 \times 10^7 L_\odot$ at 60μm, and that from the galaxies not dominated by star formation is $2.6 \times 10^7 L_\odot$ which is exactly BP's predicted value. These results support a model suggested previously (e.g. Bothun, Lonsdale, and Rice 1989) in which most of the infrared emission in a typical galaxy is due to dust heated by the diffuse interstellar radiation field, except at 60μm where the emission is approximately doubled by contributions from star forming regions.

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