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OPTICAL AND IR LUMINOSITY FUNCTIONS OF IRAS GALAXIES

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ABSTRACT

The optical and infrared luminosity functions are determined for a 60μm flux-limited sample of 68 IRAS galaxies covering a total area of 150 degrees squared. The IR function is in good agreement with that obtained by other authors. The shape of the optical luminosity function is similar to that of optically selected galaxy samples. The integrated light of most objects in our sample have [NII] to Hα line flux ratios characteristic of HII-region galaxies. In the absolute magnitude range M_J = -18, -22 about 14% of late-type galaxies are IRAS galaxies. The apparent companionship frequency is about twice as large as that for a comparable sample of non-IRAS late-type galaxies.

1. INTRODUCTION

The aim of this study is to construct the infrared luminosity function of IRAS galaxies and to compare various properties of an infrared selected sample of IRAS galaxies to those of optically selected non-IRAS galaxies.

We have selected all candidate galaxies listed in the IRAS Point Source Catalog (Beichman et al. 1984) with high or medium quality 60μm fluxes ≥ 0.5 Jy in six 5° x 5° fields at galactic latitude $|b| > 30°$. These fields are covered by the photographic plates of fields SP6, NP4, NP5, NP6, NP7, and NP8 used by Kirshner et al. (1978 (KOS), 1983 (KOSS)) to determine the optical luminosity function of field galaxies. This yields a sample of 81 IRAS candidate galaxies, 42 of which are previously catalogued galaxies, 38 are identified as galaxies on the KOS/KOSS plates, and 1 appears to be a blank field. The resulting density of these objects is ∿ 0.5 galaxy per degree squared. Published velocities are available for 24 objects. We have remeasured some of these (no discrepancies) and obtained new velocities for 45 galaxies, with an accuracy of 100 km/s, using the IIDS at the Kitt Peak 2.1-m telescope. Velocities are still missing for 12 galaxies in our sample, half of which are in field SP6, and most of which are optically faint.

Integrated optical magnitudes in the J band (KOS) have been measured with the Yale PDS microdensitometer from the KOS/KOSS plates. The zero-points of the photometry have been determined to an accuracy of 0.1 mag by comparing our results to those of KOS and KOSS. Our final magnitudes have an accuracy of better than 0.2 mag. They are corrected for galactic absorption as in KOS, but no k correction is applied. With the magnitude of 1 galaxy still missing, the sample of IRAS galaxies with available velocities and optical magnitudes considered here consists of 68 objects. No corrections for incompleteness will be made.

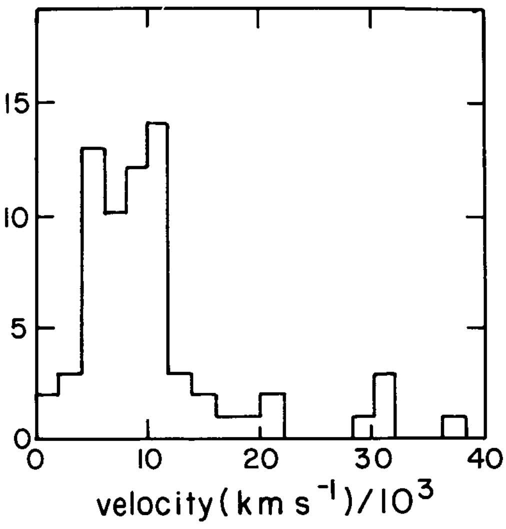

Fig. 1. Velocity distribution of our sample of 68 IRAS galaxies.

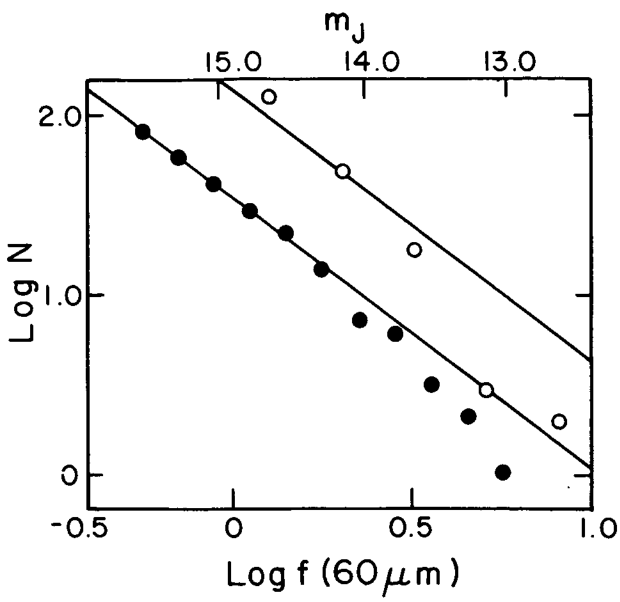

Fig. 2. Cumulative number of IRAS galaxies versus f(60μm) (•) and of KOS galaxies versus m_J (o). Solid lines indicate the expected slope for a complete sample.

2. THE INFRARED LUMINOSITY FUNCTION

The velocity distribution of our sample is shown in Fig. 1. A plot of the cumulative number of galaxies versus 60μm flux density shows that our sample is complete at the faint end but is deficient in bright objects (Fig. 2). A similar behaviour appears in the optical sample (m_J < 14.9) of KOS/KOSS in the same fields.

Absolute IR luminosities are calculated according to $L(60\mu m) = 4\pi D^2(\nu f_\nu(60\mu m))$, with D the distance of the galaxy assuming a uniform Hubble flow with H = 75 km/s/Mpc. Our differential IR luminosity function (Fig. 3a) and those obtained by Lawrence et al. (1986), Smith et al. (1986), Soifer et al. (1986), and Weedman (1986) all agree within a factor of 2 when the same units and scale factors are used.

3. THE OPTICAL LUMINOSITY FUNCTION

With only one exception all the objects in our IRAS sample can be identified optically on the KOS/KOSS plates. We therefore construct an optical luminosity function according to ϕ (opt,i) = sum(j) Nij/Vj, where Nij is the number of galaxies within absolute optical luminosity bin i and IR luminosity bin j and Vj is the corresponding volume sampled in the infrared.

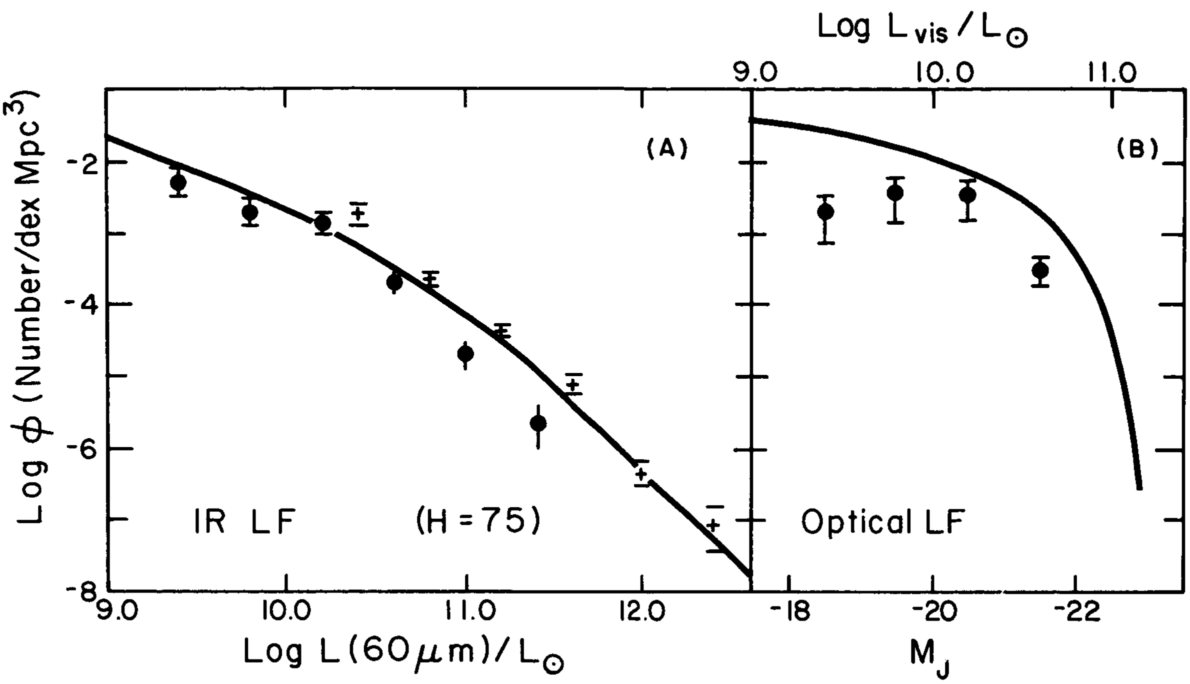

Fig. 3. (a) The differential IR luminosity function of our sample (•), of Lawrence et al. (1986, solid line), and of Soifer et al. (1986), +); (b) the optical luminosity function of our sample (•) and of Kirshner et al. (1979, solid line).

In other words, we assume that the volume sampling is determined by the IR flux limit. This hypothesis can be tested to some extent by varying the IR flux limit of our sample. We find that for 60μm flux limits ranging from 0.5 Jy (68 objects) to 0.9 Jy (31 objects) the optical luminosity functions thus derived are identical within the errors. The results for our 68 IRAS galaxies are displayed in Fig. 3b. The shape of this optical luminosity function is similar to that obtained by Kirshner et al. (1979) for their optically selected sample of field galaxies. For $-22 \leq Mj \leq -18$ the average ratio of IRAS to field galaxies is 1/7.

4. SPECTRAL CHARACTERISTICS AND COMPANIONSHIP FREQUENCY

Our spectrophotometry was principally in the red, so that the spectral diagnostics available are the Hα, [HII], and [SII] lines. The Hα line is invariably the strongest. The [NII] λ6584 to Hα line flux ratios lie in the range 0.1 to 1.0 characteristic of HII region-like galaxies (Baldwin et al. 1981). This suggests that the integrated optical spectrum of the majority of IRAS galaxies is dominated by starburst rather than nuclear activity. The absolute Hα luminosity (uncorrected for internal extinction) is proportional to the 60μm luminosity, but with a large scatter. Converting the Hα flux into Lyman continuum flux using standard recombination theory and assuming that the ionizing flux is solely due to OB stars (Salpeter IMF, mass range 6 to 40 M_0) whose optical luminosity is completely absorbed and reemitted at 60μm, we predict a relation log L (Hα [erg/s]) = log $(L(60\mu m)/L_0)$ + 30.8. While M82 approximately does obey this relation, the galaxies in our sample have Hα luminosities smaller than predicted by a factor of 20 on average. This is probably due to much larger optical extinction in our sample and a possible contribution to the 60µm luminosity of the general underlying stellar population besides that of the ionizing OB stars alone.

Enhanced star formation and nuclear activity are often found in interacting galaxies (e.g. R.M. Cutri, this volume). We have compared the frequency of apparent companions within a projected solid angle of 100 kpc for our sample of IRAS galaxies to that of 40 non-IRAS late-type galaxies in the same KOS/KOSS fields. We find that 43±8% of the IRAS galaxies have such a companion as compared to only 23±8% of the non-IRAS galaxies. In spite of the uncertainty due to projection effects, it is interesting that the apparent companionship frequency among IRAS galaxies appears to be higher, at a statistically significant level, than among the non-IRAS galaxies.

We have also compared the (J-F) colors of IRAS and non-IRAS galaxies in the KOS sample (excluding E and SO galaxies). The difference is not statistically significant: for the IRAS galaxies $(J-F)_{avg} = 0.84 \pm 0.04$, and for the non-IRAS galaxies $(J-F)_{avg} = 0.78 \pm 0.02$.

5. CONCLUSIONS

Within an absolute magnitude range $-22 \leq M_J \leq -18$ about 14% of late-type galaxies are IRAS galaxies. The integrated light of IRAS galaxies mainly reflects an enhanced star formation rate which, however, does not affect their J-F color. The probability of a galaxy being an IRAS source seems to be larger when a companion is present within a projected radius of 100 kpc.

A detailed account of this work will be submitted for publication to the Astronomical Journal.

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