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The ISO–IRAS Faint Galaxy Survey

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Abstract. The ISO–IRAS Faint Galaxy Survey will obtain comprehensive space- and ground-based observations of the most distant and luminous galaxies in the IRAS Faint Source Survey. ISO observations are obtained by filling short gaps in the ISO observing schedule with pairs of 11.5μm ISOCAM and 90μm ISOPHOT observations. As of the October 1997 date of this Conference, over 500 sources have been observed by ISO with an ISOCAM detection rate exceeding 80%. Ground-based spectrophotometry confirms that the IIFGS efficiently detects moderate-redshift, strong emission line Luminous Infrared Galaxies. Spectrophotometry is currently available for 67 galaxies with $0.07 < z < 0.7$ and $L_{fir} > 10^{11} L_{\odot}$. The galaxies are comparable to nearby LIGs, showing HII/Liner excitation; about 10% exhibit strong AGN characteristics.

As a part of this survey we will cover over 1.25 square degrees of sky to an 11.5μm limit of approximately 1.0mJy, allowing a sensitive estimate of the 11.5μm $logN$–$logS$ Relationship. Preliminary 11.5μm source counts suggest substantial evolution in the mid-infrared galaxy population.

1. The ISO–IRAS Faint Galaxy Survey (IIFGS)

The IIFGS consists of 3776 sources from the IRAS FSS selected to be fainter than 300 mJy at 60μm, with galaxy-like infrared colors, galactic latitude $b^{II} > 30°$, and a high value of the $S_{60\mu m}/S_{blue}$ flux density ratio. The combination of

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faintness at $60\mu m$ and high value of infrared-to-optical flux-density ratio leads to a selection in favor of the most luminous and highest redshift candidates since there is a strong correlation between L_{fir} and $L_{60\mu m}/L_{blue}$ for infrared-bright galaxies (Soifer *et al.* 1987). Optical candidates and magnitudes for each source were obtained from the IPAC's OPTID Program; 60μm sources were selected if they had a blue counterpart fainter than about 17.5 mag. in the northern sky and 19 mag. in the southern sky. Full details of the selection procedure will be given in Lonsdale *et al.* (1998a).

The IIFGS sample galaxies are scheduled for observation by ISO on a "Filler" basis: IIFGS sources are selected to fill gaps in the ISO observing schedule once higher priority targets have been scheduled. Thus the IIFGS serves to enhance the total observing efficiency of the mission. Of the 3776 candidate IIFGS sources in the ISO observation database, over 500 have been observed as of October 1997 and it is expected that over 600 will be observed before the end of the ISO mission, with a total sky area coverage of nearly 1.5 square degrees.

The IIFGS sample will represent one of the best and largest deep samples of infrared-luminous galaxies until the advent of WIRE (Wide-Field Infrared Explorer) and SIRTF, even though it is based on selection from the fourteen year old IRAS survey. ISO cannot easily probe significantly deeper in redshift than the IRAS Faint Source Survey because the excellent sensitivity of ISO's best photometric survey instrument, ISOCAM, is offset by the declining infrared spectral energy distribution from $60\mu m$ (the most sensitive IRAS band for galaxies) to the shorter mid-infrared wavelengths of ISOCAM.

2. ISO Observations

ISO observations are obtained using the the ISOCAM (Cesarsky *et al.* 1996) LW array with the "IRAS $12\mu m$" LW10 filter and ISOPHOT (Lemke *et al.* 1996) C100 detector with the C90 – $95\mu m$ filter. The ISOCAM observations, with positional uncertainty better than about 12 arcsec, provide confirmation of optical identification, and the 11.5 and $90\mu m$ photometry, combined with IRAS data provide mid- to far-infrared spectral energy distributions. The overall detection rates for IIFGS sources are quite high: the ISOCAM $11.5\mu m$ detection rate is approximately 80% for 418 sources processed thus far, with a typical detection limit of approximately 1.0mJy (5σ); with 140 sources processed, the ISOPHOT detection rate is approximately 50% to a limiting flux density, $S_{90} \sim 70\mathrm{mJy}(5\sigma)$. Considerable continuing effort is being dedicated to ISO data analysis as described in Levine *et al.* (1998) and Hurt *et al.* (1998) with the expectation that positional uncertainties, photometric accuracy, and perhaps detection statistics will improve.

3. Optical Spectrophotometry

Optical spectrophotometry and imaging are being obtained at Lick and Palomar Observatories in order to obtain redshifts, morphologies and optical/near-infrared photometry. Redshifts have been obtained for 57 IIFGS galaxies as shown in Figure 1.

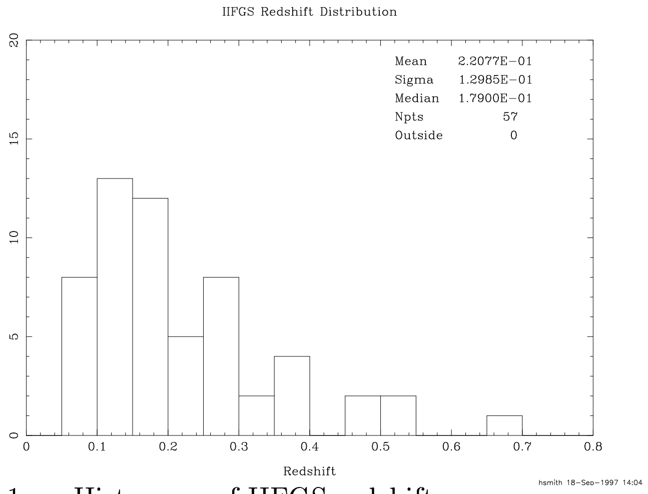

Figure 1. Histogram of IIFGS redshifts.

The spectra typically show strong line emission with excitation near the HII/LINER/AGN boundary typical of nearby LIGs. About 10% of the galaxies show true AGN characteristics: very high excitation and/or emission-line widths of several hundred km/s. The optical-infrared spectral energy distributions for 9 galaxies with complete photometry are shown in Figure 2. In general, the IIFGS galaxies are well matched by the SEDs of well-studied LIGs, and the sample follows the same photometric relationships as BGS galaxies (*e.g.* they inhabit the upper end of the L_{60} *vs* L_{60}/L_{blue} relationship with BGS LIGs). Unfortunately, as with nearby LIG samples, it is not straightforward to infer the dominant power source — starburst or AGN — from the SEDs alone (Smith, Lonsdale & Lonsdale 1998). In Figure 2 the source F15390+6038 stands out as having a large mid- to far-infrared flux-density ratio but a steep mid-IR to optical slope. This source, at $z = 0.377$, is also the highest excitation Sy spectrum among the IIFGS galaxies with a $60\mu m$ luminosity, $L_{60} \approx 10^{12} L_{\odot}$.

4. $11.5\mu m$ Source Counts

The IIFGS ISOCAM observations will cover a fully sampled area of about 1.3 square degrees of sky, roughly half of which will be outside of the IRAS error ellipses which define our target areas. The flux completeness limit is expected to be approximately 0.6-0.8 mJy. We are searching these fields for "serendipitous" $11.5\mu m$ sources in order to construct an estimate of the $log\,N$–$log\,S$ relationship and to identify candidate sources for follow-up observations. Preliminary analysis of 418 fields covering approximately 0.4 square degrees yields about 60 sources with fluxes of $0.6 < S_{11.5} < 25$mJy. Though more work must be done on proper flux calibration and calculating the true arial coverage as a function of flux, these preliminary results hint at possible strong evolution of the mid-infrared galaxy/AGN population.

We have initiated a program of follow-up spectroscopy of ISOCAM serendipitous sources at Lick and Palomar observatories. Further follow-up programs are being proposed with ISO, SCUBA and elsewhere for detailed studies of the most interesting and highest redshift IIFGS sources.

References

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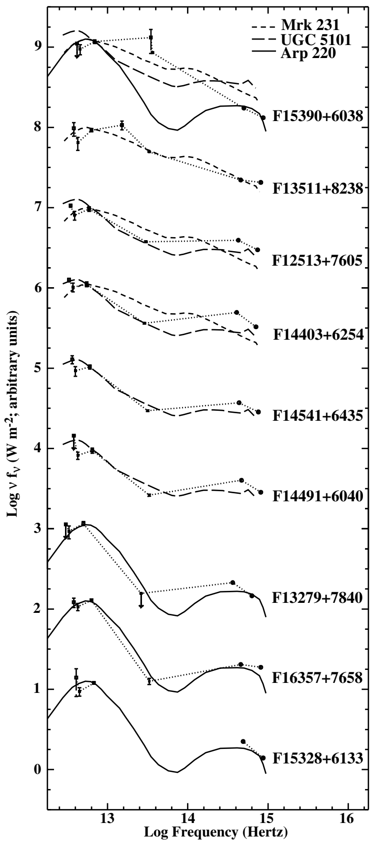

Figure 2. Optical–FIR spectral energy distributions for 9 IIFGS galaxies. Plotted are Lick "G"(λ4700) and "I"(λ8275) band photometry, our ISOCAM 11.5μm and ISOPHOT 90μm measures, as well as IRAS 60 and 100μm data. Plotted for comparison are the SEDs ofArp 220 (pure starburst, solid line), UGC 5101 (intermediate AGN, long-dashed line), and Mrk 231 (IR QSO, short-dashed line).